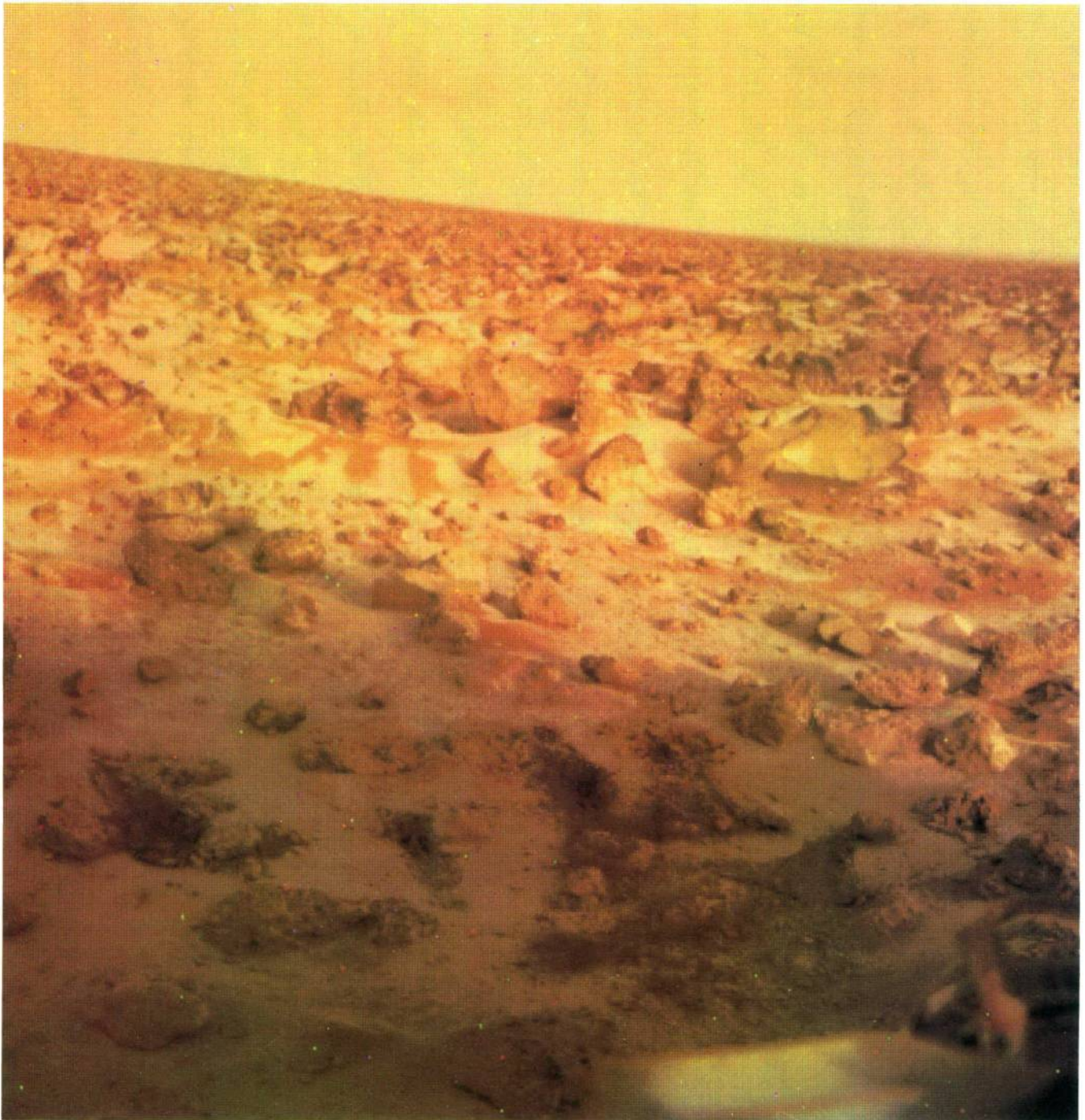


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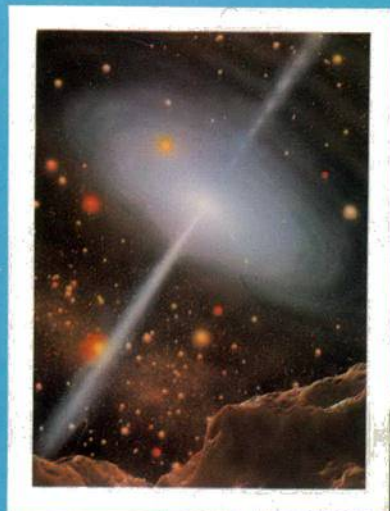
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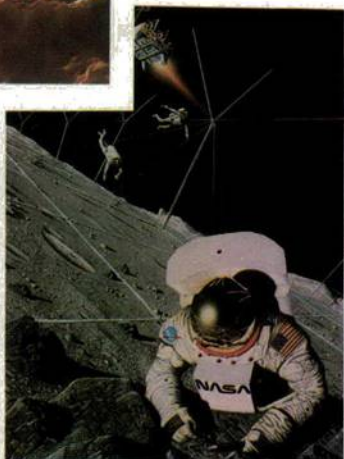


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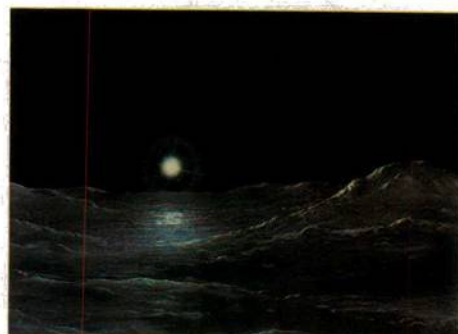
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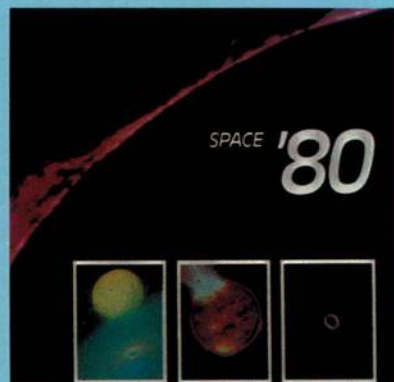
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ASTRONOMY

Vol. 7, No. 10

October 1979

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6 Using Earth as a Radio Telescope
by Richard Isaacman

14 NGC-1275

16 A Voyager Album

Forum 24 A Personal Voyage to Jupiter
FAR OUT — by Jove!

Sky Almanac 30 A Plentiful Harvest of Planets

Equipment Atlas 36 Buyer's Guide to Telescopes

Gazer's Gazette 42 Saturn's Vanishing Rings

Gazer's Gazette 47 The Top 21 Deep-Sky Objects

Photography in
Astronomy 52 How to Get Steady Pictures

Astronomy Reviews 56

AstroNews 58

Stellar Frontiers 66 The Cosmological Principle
by Paul S. Wesson

In Focus 71

Astro-Mart 73

Star Dome 80 Cepheus

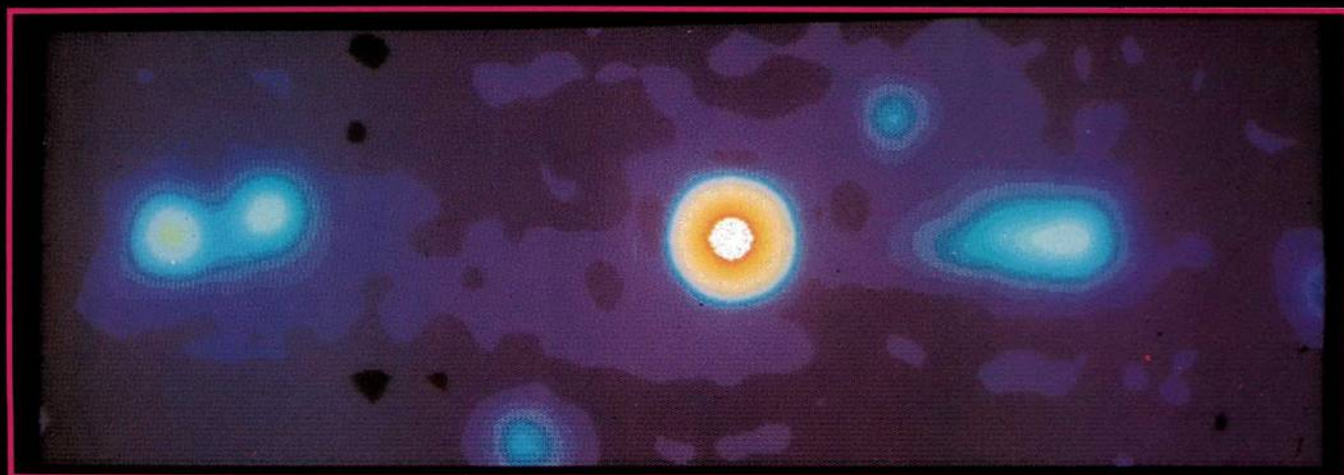
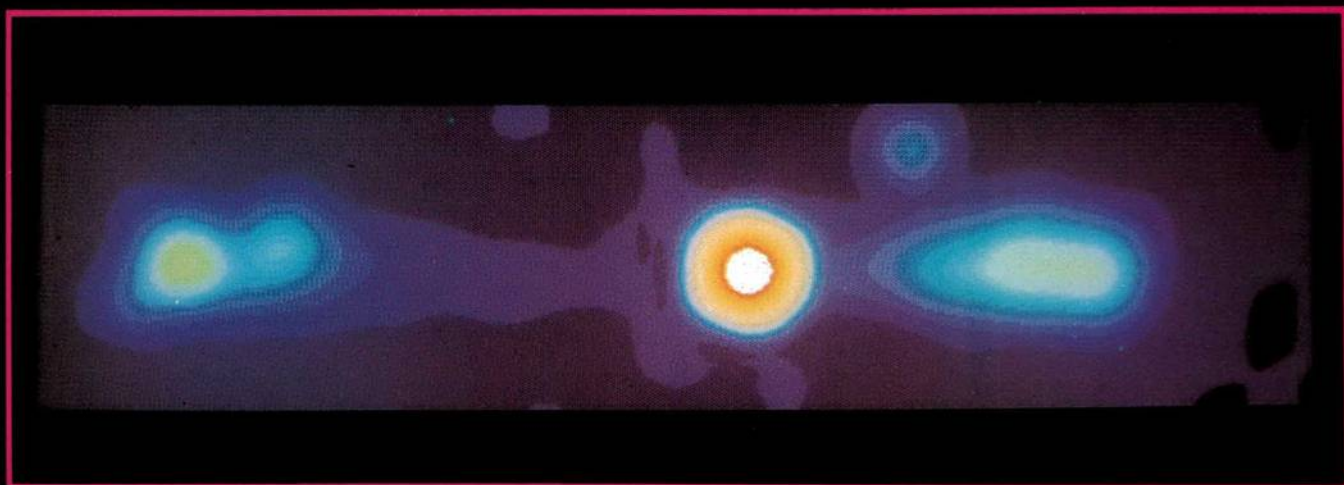


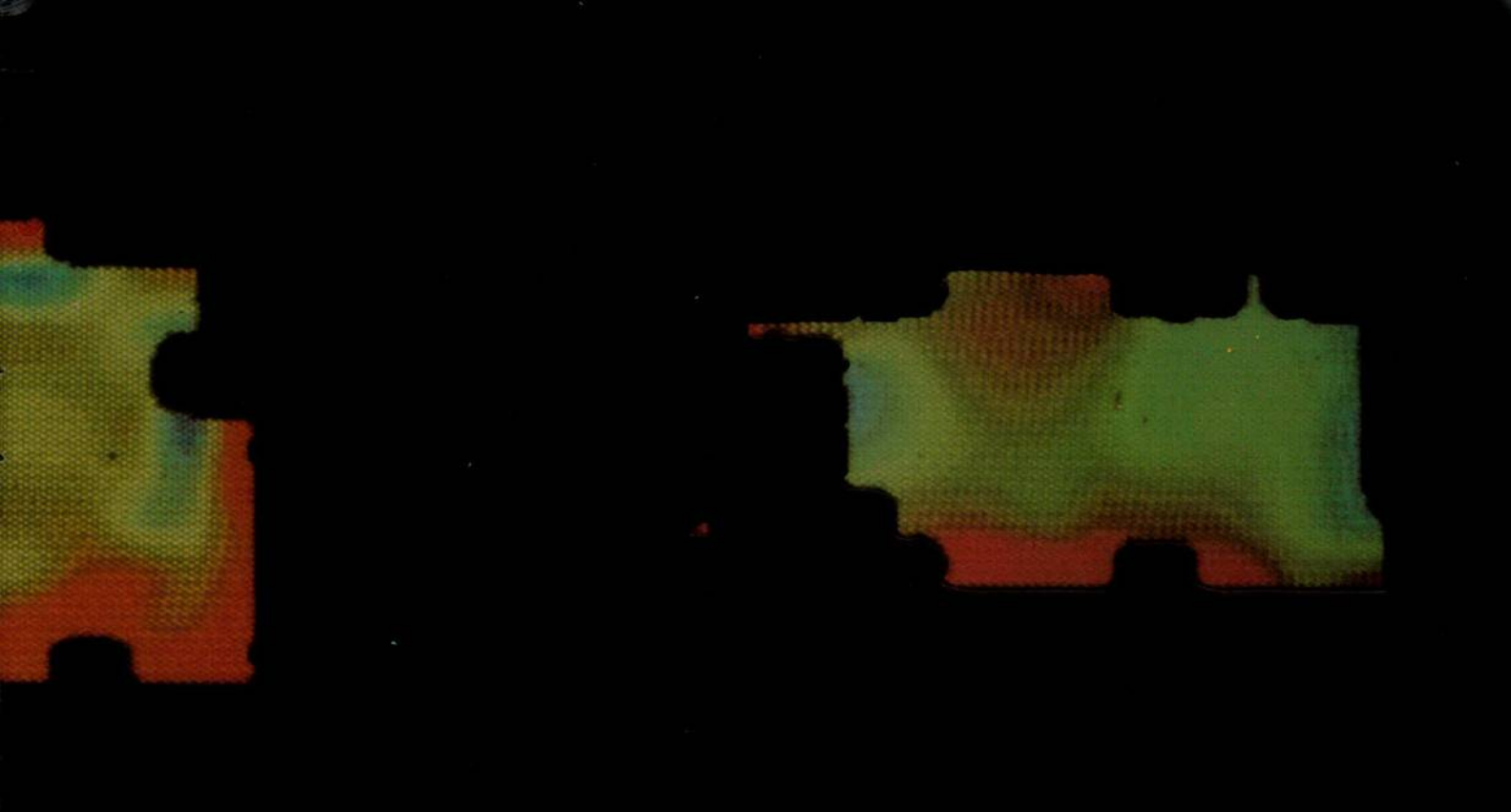
Cover: It's winter again at the Viking Lander 2 site on the Plains of Utopia, and this year the "snow" (really an ice layer perhaps as little as one-thousandth of an inch thick) is back right on schedule. The picture was taken by cameras aboard the Lander on May 18, stored on magnetic tape, and relayed to Earth via Viking Orbiter 1 on June 7. See AstroNews for more information and a wide-angle photograph. This month, ASTRONOMY presents more of the latest Voyager photographs, takes a look at powerful new techniques in radio astronomy, and names the "Top 21" objects for your telescope.

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Spread across the top of these pages is the largest object known in the universe. With an apparent angular size of 39 minutes of arc — larger than the full moon — 3C 236 extends 18 million light-years end to end and fills a volume of space greater than most clusters of galaxies. This image is a computer-generated spectral index map of 3C 236, which shows by color coding the ratio of emission strengths at two different radio frequencies. The two separate images used to construct the above map are seen below, as revealed by the Westerbork radio telescope array. The one at top is 3C 236 at a radio wavelength of 50 centimeters, while the one below is at 6 centimeters. Note the double lobes arranged on either side of the bright central image, which corresponds to a giant elliptical galaxy. Such detailed images as these have only recently become possible, with the advent of a new generation of giant radio telescopes, some of which effectively span the entire Earth. Photos courtesy of Leiden Observatory.





Using Earth as a Radio Telescope

by
Richard Isaacman

To match the resolution of even a very tiny optical telescope (or even a good pair of human eyes), astronomers need a radio telescope of monumental size. If that seems a bit far-fetched, then compare the resolution of the largest single-dish radio telescope in the world — the tremendous 1000-foot Arecibo telescope in Puerto Rico — with that of your eye. The Arecibo dish typically works at the important 21-centimeter (about $8\frac{1}{2}$ -inch) wavelength of neutral hydrogen atoms, and at that wavelength it has an angular resolution of roughly three arc-minutes — about half as good as your eyes. Your eyes, receiving visible light and working at a wavelength of $1/50,000$ of an inch, can — and do — form as sharp an image as the largest radio dish in the world.

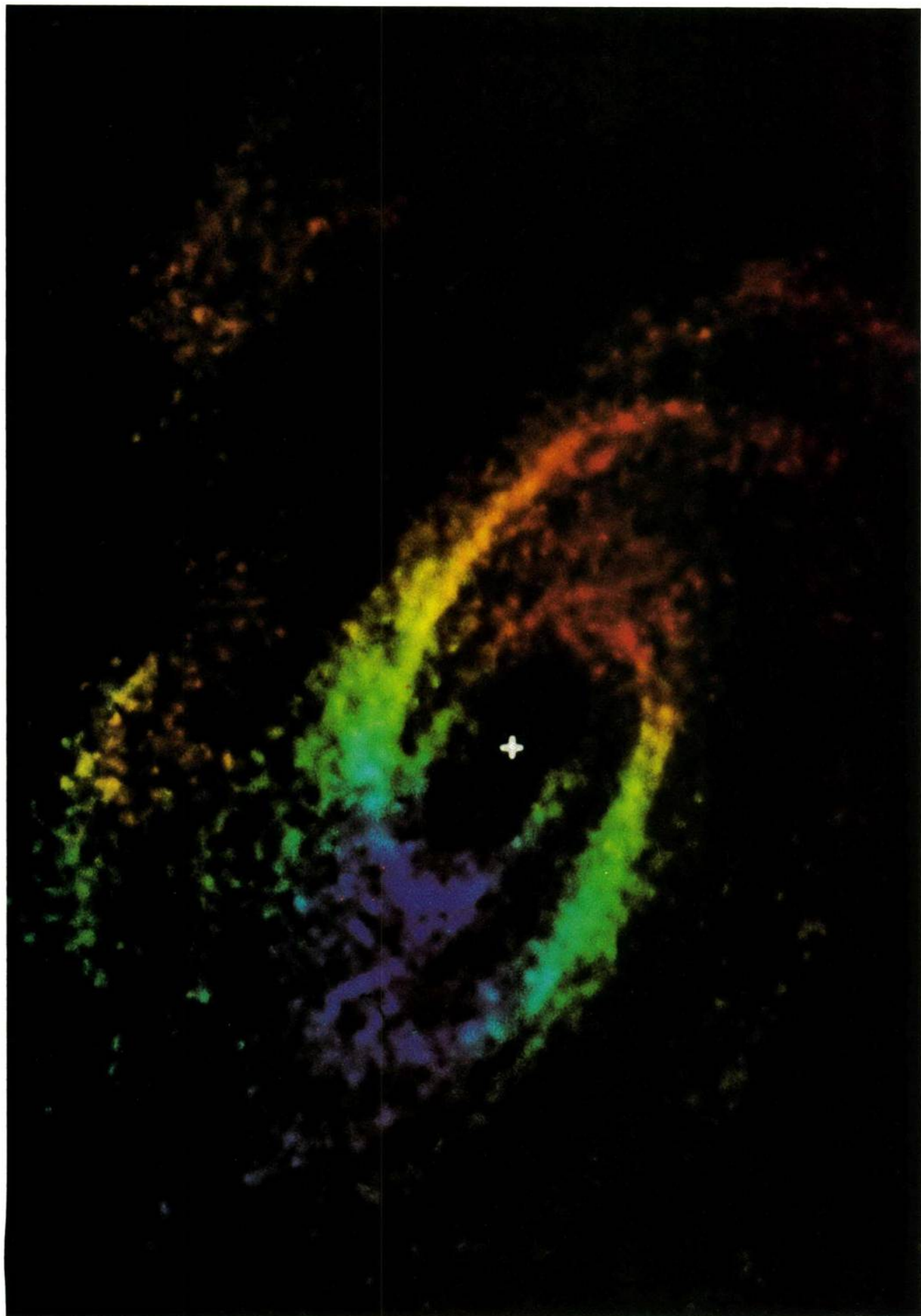
Large optical telescopes come nowhere near diffraction limited performance. Because of turbulence in the Earth's atmosphere, the image of a star blurs and twinkles. Under the best of conditions, in carefully chosen sites, photographic star images are a little under 1 second of arc across (or about $1/3600$ of a degree). If, in fact, the 200-inch Hale telescope could be operated at its diffraction limit — as NASA's orbiting Space Telescope will be when it's launched — then its performance could be improved 50 times.

Radio telescopes are another matter. Radio waves are very large compared to light waves, and the wrinkles and vagaries of the Earth's

atmosphere mean very little to them. But their very size means that radio telescopes — special instruments built to gather and focus radio waves for scientific study — are limited basically and fundamentally by the radio waves themselves. Radio telescopes are diffraction limited — but what a limit it is!

This is a direct consequence of the fact that the 21 centimeter wavelength often used by this radio telescope is 400,000 times longer than typical wavelengths for light. The angular resolution of a telescope depends on how wide its collector is in terms of the wavelengths of the energy it's collecting: a collecting dish or mirror only five or ten wavelengths across can't distinguish clearly where a signal is coming from. The twin images of two objects close together get blurred into a single image. An astronomer might say its angular resolution is 10° . We would say it produces a fuzzy image.

A large optical telescope with a mirror diameter measured in millions of wavelengths — even a little homemade telescope with a mirror only 100,000 wavelengths across — can distinguish quite precisely where energy is coming from and separate close images. The resolution of optical telescopes is measured typically in thousandths or ten-thousandths of a degree. To achieve the same resolution one of the world's major optical telescopes can provide for optical astronomers, radio astronomers would have to build a radio



telescope over 18 miles across. This is clearly out of the question.

Or is it?

A radio telescope and an optical reflector, though considerably different in size and appearance, work on essentially the same principle. Both collect electromagnetic energy which, depending on the circumstances, a physicist may call either waves or photons. In both instruments, the energy is reflected from the dish and concentrated at the focus for detection. In an optical telescope, detection may be a photographic plate, a human eye, or an electronic device; in a radio telescope, detection is always with a sensitive radio amplifier.

But there's no reason — at least in principle — why we can't just saw the collector (dish or mirror) in half, move the pieces to different locations, and use the two halves to look at the same celestial object at the same time. Though they're gathering energy separately, if a clever astronomer combines the two signals by running them through some wires, he can, in effect, build a very big telescope by combining little telescopes. It turns out to be technically feasible to combine radio energy in this way (because the long wavelength isn't impossibly fussy to work with), but not feasible to combine light in this way.

A very interesting thing happens when you combine the piped-in signals from two collectors separated by some distance: the separation between the collectors — not the size of the collectors — determines the angular resolution!

Actually, we would have what is called an *interferometer*, because the information we extract is a result of interference between the two signals when we combine them. The telescope resulting is a long, skinny one, of course, because it actually consists of only the ends with nothing in between.

With this technique at our disposal, our 18-mile radio telescope (and the superb resolution it offers) is no longer a pipe dream — in fact, it is two years from completion in New Mexico, and has already begun operation. The Very Large Array (VLA) is a collection of superlatives: when completed, it will be by far the largest (and, at \$72 million, the most expensive) radio telescope in the world. The Very Large Array will consist of 27 dishes, each 25 meters (83 feet) in diameter, spread out in a "Y"

If we had "radio eyes" sensitive to the 21 centimeter line of neutral hydrogen, the spiral galaxy M-81 would look like the image on the facing page. In this view, we can actually see the galaxy rotating, for the colors correspond to the Doppler shift of the rotating gas within it. Radio waves from material moving toward us (at up to 150 miles per second) is seen at slightly shorter, "bluer," wavelengths than 21 centimeters, while that moving away from us (at up to 100 miles per second) is slightly longer in wavelength, therefore appearing "red" to our radio eyes. The featureless region near the center of the galaxy indicates a lack of interstellar hydrogen gas, which is all we can see in this radio wavelength region of the spectrum. In reality, we know that the center of the galaxy contains a vast number of stars, many more than in the spiral arms. Photo courtesy of the Netherlands Foundation for Radio Astronomy.

shape. Each leg of the "Y" will be 13 miles long and have nine antennas. The antennas of the Very Large Array will operate as an interferometer, but a much more complex interferometer than the simple "two-element" one consisting of one collector at each end. The extra antennas "fill in" the missing parts of an imaginary giant collector a full 18 miles across, giving better performance than a simple interferometer could, and collecting more radio energy.

As of summer 1979, more than half of the dishes have been completed and installed. It's clear why such a thing is being built out in the desert: besides being reasonably free of interference from radio and TV stations, a desert is the only place with enough room!

The VLA has a nine-year-old relative in northern Holland — the Westerbork telescope. Westerbork has 14 dishes, also each 25 meters across, arranged in a single line nearly a mile long. The Westerbork telescope achieves very high angular resolution by making use of the technique known as *aperture synthesis* in which a computer adds up millions of individual interferometer observations to make a complete radio picture.

Operating at a wavelength of 21 cm with the aperture synthesis technique, the mile-long Westerbork array has a resolution of about 22 seconds of arc — eight times better than the Arecibo dish, and three or four times better than your eye. In addition, in 1980 two of the Westerbork array elements will be moved another mile, doubling the length of the array and doubling its ability to resolve close radio sources.

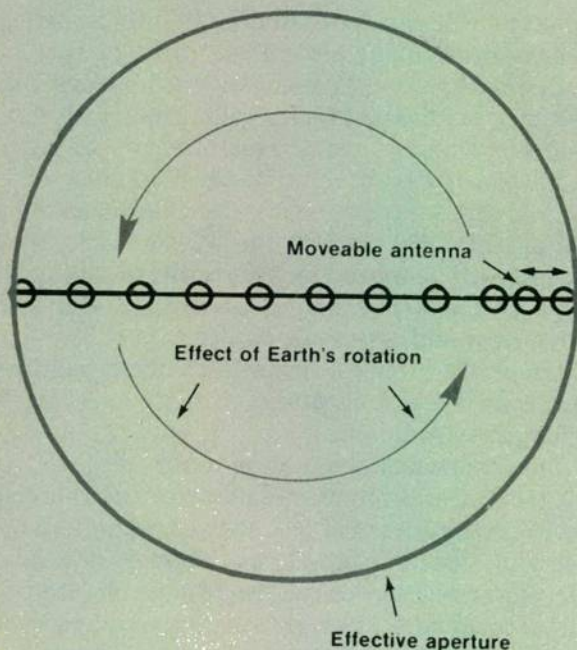
Large optical telescopes still do about ten times better than this but, of course, work at wavelengths 400,000 times smaller.

The enormous amount of data recorded by radio telescopes is sometimes displayed as a contour map. With the advent of fast computers and image-processing systems, though, astronomers now favor radio pictures. By representing the radio intensity data points as dark or bright spots on a video screen, an astronomer can instantly convert a string of numbers stored on a magnetic tape into a radio photograph.

Additionally, color provides a flexible way to represent a another "dimension" besides two position coordinates and brightness. Since no one can "see" radio waves, the computer programmer can define radiograph colors to suit his needs. Perhaps the most straightforward display colors are analogous to the colors of light: short wavelength radio emissions are displayed in blue, intermediate wavelengths in yellow and green, and long wavelengths in red. In this way, radio astronomers can display, for example, the Doppler shift of radio spectral lines in a rotating galaxy. Never has galactic rotation seemed so real: a rotating spiral galaxy viewed partly edge-on (see page 8) shows the approaching edge as blue because

What is Aperture Synthesis?

We can't do much useful observation with a long, skinny telescope like the Westerbork telescope, 1500 meters long and only 25 meters wide, unless we want to look at long strips of the sky. Unlike a circular aperture, that arrangement would give us a very sharp angular resolution in one direction (parallel to the array) and very poor resolution in the perpendicular direction. There are a few ways out of the difficulty, though: we could, for example, build a second row of antennae perpendicular to the first, making an "X" or "T" shape. Several instruments have in fact used that arrangement. Instead of building all the elements of the perpendicular arm, though, we might also use just a single antenna that can move back and forth along a track. By taking measurements at different positions at different times, we can in effect simulate a full set of antennae along the cross arm. Adding together the observations at each position in combination with the main row of antennae results in an artificially synthesized circular aperture. For this reason, the technique is called aperture synthesis.



If we don't want to bother with the perpendicular arm at all, but could somehow rotate the whole linear array about its midpoint, then we could synthesize a single giant circular "dish" whose diameter is equal to the length of the array. We can indeed perform such a feat. We can hardly avoid it, in fact, because the Earth's rotation swings us and our array around in a circle every day. Both Westerbork and VLA work on this principle, appropriately called earth rotation aperture synthesis, or (more grandiosely) supersynthesis. A complete supersynthesis observation takes 12 hours — not a whole day since, as you can easily visualize, any position of the array with respect to the sky after more than 12 hours will be just the mirror image of an orientation that has already occurred.

In this way, a number of much smaller radio antennae can be made to perform effectively like a single giant antenna miles across.

the 21 centimeter line of interstellar neutral hydrogen has shifted a tiny amount towards shorter wavelengths, while the other edge displays as red because the radio is shifted to longer wavelengths as it moves away from us.

Colors can also be used to indicate brightness, simply making the pictures more interesting to look at. Alternately, colors can display more exotic or technical information, such as steepness of spectrum or direction and degree of polarization.

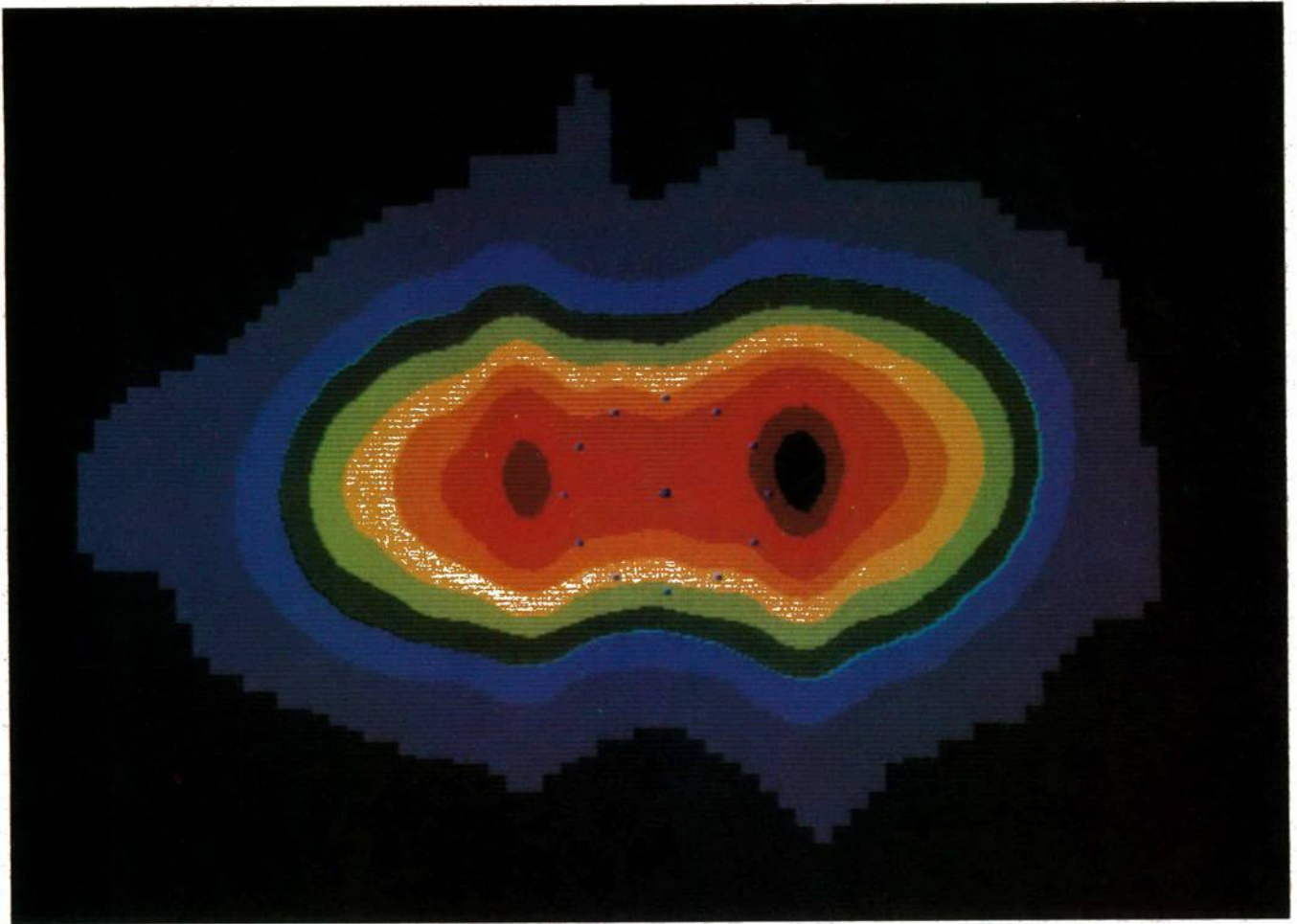
Radio telescopes — and the field of radio astronomy — have truly come of age. Now that radio astronomers can achieve an angular resolution as good (or better as we'll soon see) than optical telescopes, and can present the mountains of data in a useful way, it's fair to ask: "What is there to see?". Actually, we'll have to ask it twice, because radio astronomers live in two worlds: the thermal and the nonthermal.

The thermal universe is the universe of "classical" astronomy, and is the one which we as living creatures inhabit. Thermal energy is the radiation of hot gases and solid bodies, from the visible incandescence of stars to the radio emission from interstellar gas. An optical telescope, of course, sees the stars, while a radio telescope detects the gases — a difference that becomes clear as soon as we see a radiograph of, say, any nearby spiral galaxy. At first glance, it strongly resembles an optical photograph; indeed, with the high angular resolution of aperture synthesis, it is almost as sharp as the optical image. The spiral arms, for example, stand out clearly. But in the optical photo they're delineated by concentrations of bright stars; it is the ionized gas in the arms that we see on the radiograph.

The innermost regions of spirals tell a different story. Jam-packed with stars — and therefore optically bright — galactic nuclei tend to be depleted of gas, and they appear empty — or dark — on radiographs. Exactly why no one knows: it may be that all the gas has been used up in the formation of stars, or that occasional titanic explosions blow all the gas out. Many spiral galaxies — including our own — show some evidence of having undergone some sort of violent activity in the past; indeed, some appear to be experiencing it now. When they do, they enter the realm of nonthermal radiation.

Nonthermal radiation usually means violence. Supernovae and exploding galactic nuclei liberate unimaginably vast amounts of charged particles, usually racing close to the speed of light. When these encounter magnetic fields, they are forced to change course and, in protest, they emit intense, narrow beams of radio radiation. All of the most energetic radio sources in the sky radiate in this way.

A typical example is the giant elliptical galaxy DA 240. Roughly 600 million light-years away, DA 240 appears in optical radiation — on photographs — as a fuzzy patch about 30 seconds of arc across.



The intense radiation belts of Jupiter appear clearly in the radiograph above, prepared from observations made with the Westerbork Synthesis Radio Telescope. The dotted circle at the center indicates the position of the visible disk of the planet. Photo courtesy of Leiden Observatory.

The optical object is, therefore, around 100,000 light-years in diameter, or about the size of our own Galaxy. Seen with a radio telescope however, DA 240 stands out as a fantastic energy source spreading over a region of the sky bigger than the full moon. The optical galaxy itself is an intense radio source, but radiating out from it are two opposing "jets" that span a total length of 6 million light-years. The lobes line up exactly with the central source, so astronomers must ask themselves what cosmic processes could possibly eject such tremendous amounts of mass? And what forces keep the lobes aligned over such huge distances? Several models have been proposed, none of them altogether satisfactory. But radio pictures — and the data represented in them — will help us eventually answer these questions.

Closer to home, we see nonthermal emission from the intense radiation belts of Jupiter, caused by electrons trapped in the planet's intense magnetic field. The fields in Jupiter's giant version of Earth's Van Allen belts are so strong that even unmanned probes like Pioneer and Voyager enter at their peril. Jupiter's ten-hour rotation period also

gives us an avenue of study that is not available among distant objects that change only over cosmic time scales. By making radio maps at different times when the radiation belts are turned at different angles to Earth, we can piece together a unique three-dimensional picture of the structure of the belts.

Of course, astronomers want to explore deeper into space and make more detailed pictures than even the Very Large Array can provide. Aperture synthesis telescopes (with the exception of the VLA, which is ten times bigger) have been a few miles in diameter and have reached angular resolutions of ten to twenty seconds of arc. But if we're willing to settle for a simple "two element" array, we can place the elements of an interferometer as far apart as we want, to obtain very much higher resolution.

The only limit is the size of the Earth.

Although the astronomers can't conveniently connect their antennas by wires in order to add the signals on the spot, they can record the signals on tape at each location and play the two tapes together later. But it's not easy: in order to be able to add the signals properly, the antennas must be looking at the same source at the same time. "Same time" in this case means to within about 100 nanoseconds (100 billionths of a second) of each other. Timekeeping of this precision only became feasible a decade ago with the development of atomic

rubidium clocks, accurate to about one part in a trillion. Recently hydrogen maser devices have reached stabilities a hundred times better: one part in a hundred trillion, or about one second timing error in three million years.

With baselines of thousands of miles, Very Long Baseline Interferometry (VLBI) instruments operating at short wavelengths (2 to 6 cm) can reach astounding angular resolutions of a few thousandths of a second of arc. This is the angular size of a dinner plate in Colorado as viewed from New York (presumably on an exceptionally clear day!). In astronomical terms, this means that sources only a few times the size of the solar system — quite minute on the scale of a galaxy — could be distinguished at the distance of the galactic center, about 30,000 light-years away.

Observations of this sort may help to identify the mysterious compact energy source at the center of our Galaxy. Other galaxies may have similar objects at their cores — possibly massive black holes — which may be the engines driving the sporadic violent activity seen in the nuclei of many spirals. Without high-resolution Very Long Baseline Interferometry data, we might never know the answer.

Interferometry has some earthbound uses as well. If the positions of some celestial objects can be determined to a very high precision, then VLBI observations can be used to calculate highly accurate relative positions on the surface of the Earth. This comes back to the central role of timekeeping in interferometry: in order to be able to add the signals from two independent locations, we must be able to time the observations to within one cycle of the appropriate frequency. This is the equivalent to knowing the distance between the stations to better than one wavelength, which is typically only a few centimeters, or about an inch. By making observations over a period of several years, it should therefore be possible, for example, to measure continental drift directly.

One of the major technical limitations of Very Long Baseline Interferometry has been the difficulty of making simultaneous observations with well-separated telescopes running off independent clocks. There have now been proposals to synchronize the clocks at the radio telescopes participating in the observations, and to combine the signals from their antennas using a communications satellite in geostationary orbit. If all goes well, such a system may be operating on an experimental basis within two or three years.

An extension of this concept is obvious: if we can use a geostationary satellite as a relay, why not use it as one of the stations of the interferometer? A radio telescope in synchronous orbit would provide a baseline nearly three times the diameter of the Earth. At a wavelength of six centimeters, this would provide an angular resolution of about 300 millionths of a second of arc, undoubtedly capable of

The giant elliptical galaxy DA 240 is flanked by two lobes of radio emission as seen in the radiographs opposite. The full extent of the double source spans more than half a degree in the sky, an angular diameter greater than the full moon. This corresponds to an actual diameter of over six million light-years at the estimated distance of DA 240, making this object one of the largest known in the universe. The image at top is an intensity map at a wavelength of 50 centimeters made with the Effelsberg Radio Telescope in Bonn. At bottom, DA 240 is seen at a 6 centimeter wavelength with the Westerbork Synthesis Radio Telescope. The image at center is a spectral index map of DA 240, obtained by dividing the intensities of the 6 centimeter map by those of the 50 centimeter map. This illustrates the relative emission intensity between the two wavelengths at each point. Photos courtesy of Leiden Observatory.

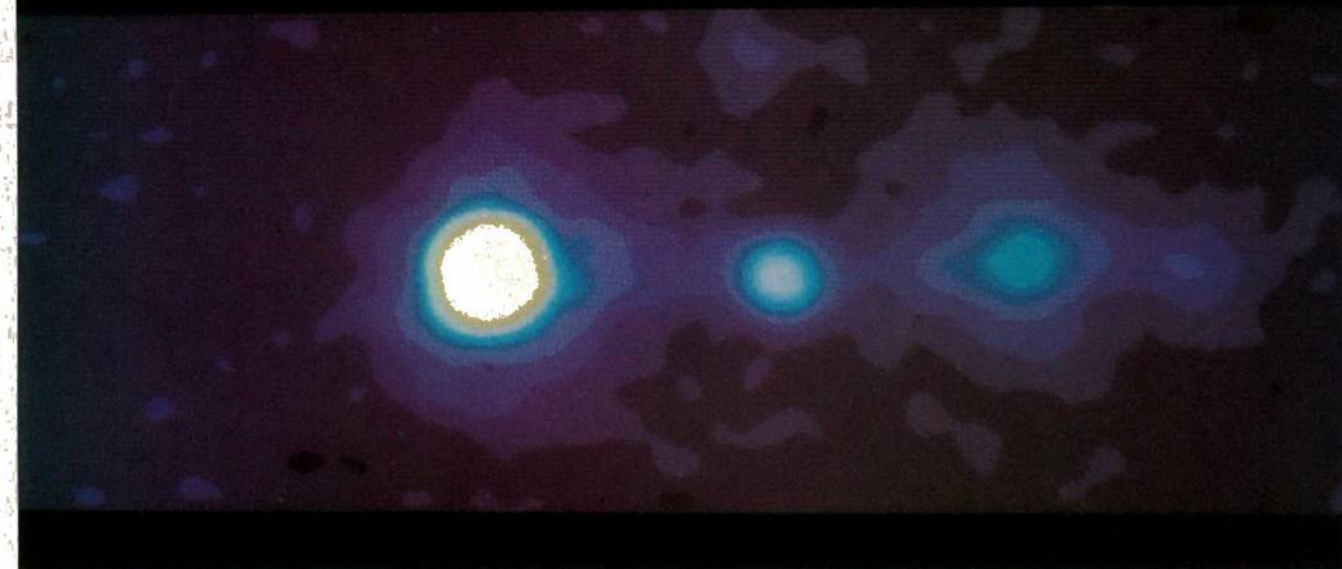
revealing more detail of the astrophysically tantalizing black holes and exotic compact sources that are now beyond the resolving power of the best arrays.

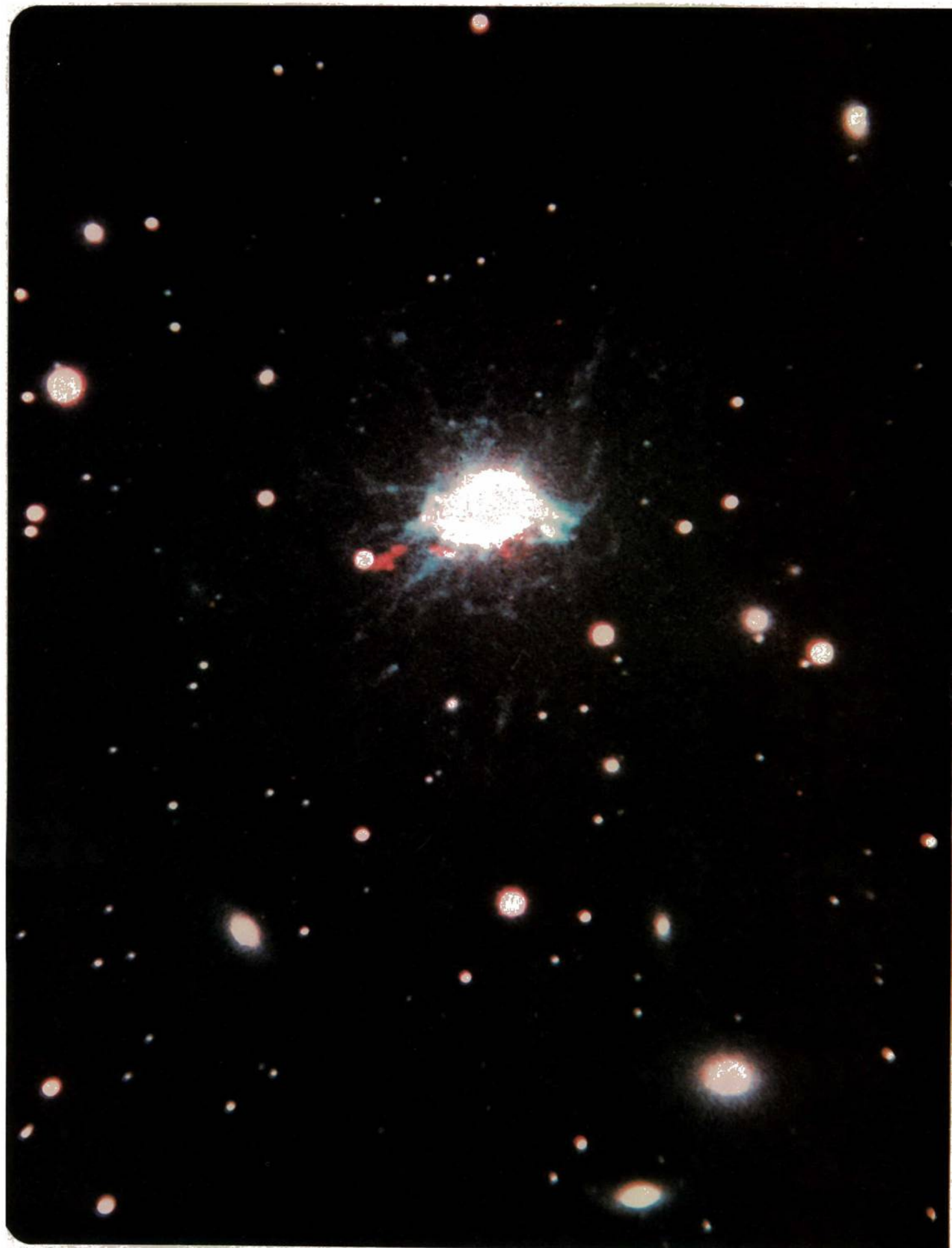
How can we be so sure that a bigger telescope is going to be better? It has been very rare in scientific research that an increase in resolving power by a factor of five or ten — or even two — has not yielded many answers to old questions, as well as raising a wealth of new ones. The double sources like DA 240, or its relative 3C 236, are a good example. The discovery of the huge double lobes extending out to a hundred times the width of the central galaxy was surprise enough, but Very Long Baseline Interferometry measurements of the intense central source of 3C 236 revealed that it is not a point source, but has two inner "jets" radiating outward. Many such double sources have turned out to be "double doubles" on closer inspection.

Even higher angular resolution observations further revealed that one of the inner lobes of 3C 236 was itself composed of two or three sources, all lined up with the outer lobes. Like a set of puzzle boxes, looking closer and closer only reveals structure on a smaller and smaller scale, ending...where? Eventually you must be able to look closely enough to see the prime mover which energizes a gigantic radio galaxy millions of light-years across.

Finally, it is worth mentioning what is perhaps the most exotic use of radio interferometry. A 1973 design study for a system for detecting extraterrestrial life proposed Project Cyclops, a 6 mile diameter array of 330 foot antennas — as many as 2000 of them. This system would use high-sensitivity receivers and advanced signal processing techniques to comb most of the sky and a significant chunk of the radio spectrum for signs of intelligent life. Like the question of extraterrestrial life itself, the question of whether Project Cyclops will ever be built — indeed, whether it should be built — is wide-open to dispute. But feasible or not, it is another example of radio telescopes spanning the Earth to reach the stars. ☛

Richard Isaacman is a member of the staff of the Leiden Sterrewacht (Dutch for "observatory") in Holland. A graduate of Cornell University, he has worked on pulsar timing at the Arecibo Observatory in Puerto Rico and is currently completing his Ph.D. thesis on a search for planetary nebulae near the center of our galaxy, using the Westerbork Synthesis Telescope.





NGC-1275

In recent years, our picture of the universe has gone through so many different changes that it's bewildering! Every few years, publishers seem to come out with yet another book entitled "The New Astronomy." In every one, much of what used to be known has been totally re-worked. It really does seem like a *new* astronomy. So many advances have been made in most sciences that it would be hard to say just which one has been the most thoroughly upset. But by anyone's measure, astronomy must rank somewhere near the top.

One of the more durable views of our universe, persisting and growing over the years, is the one that sees it as a violent place where titanic energies are released on an almost routine basis. At times it seems almost like astrophysics is trying to strain our physics (and credulity!) to the breaking point. And perhaps it is.

An outstanding astrophysical nut to crack is the problem of the energy source(s) powering certain galactic nuclei. Many astronomers are now working toward a consensus that there's a relatively smooth gradation from normal galaxies through to quasars, with the gap being filled by objects like N-galaxies and Seyfert galaxies. The N-galaxies differ from normal spirals in that they have anomalously bright, almost stellar nuclei, while Seyfert galaxies, which make up perhaps 1 in 200 of all galaxies, have nuclei proportionally brighter still.

Seyferts, like NGC-1275 on the opposite page, have nuclei so dominant they often come close to obliterating the surrounding disk. The most distant ones we can see usually have only the bright nucleus in sight. In these cases, identification must be made by spectrograph.

The chief physical difference setting them apart from normal galaxies is shown by spectroscopic evidence indicating the gases just outside the nuclei are moving at terrific velocities, often reaching thousands of kilometers per second.

NGC-1275 is a Seyfert galaxy, one of a class of abnormal galaxies characterized by extremely bright nuclei, and often showing signs of violent explosions. The photo opposite shows the extended streamers and tendrils of gas flung out of the nucleus at high velocity. Kitt Peak National Observatory photo © The Association of Universities for Research in Astronomy, Inc.

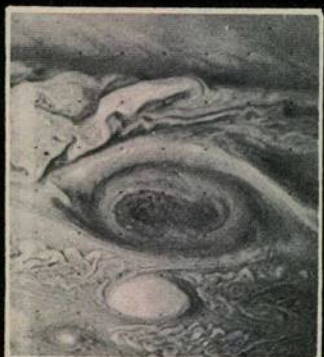
Moreover, strange abundances of ionized elements reveal that physical conditions there are exotic and violent in the extreme. It's hard not to assume that there's been some sort of gigantic explosion in their nuclei. Even a glance at NGC-1275 shows something remarkably like the supernova remnant Crab Nebula, though you'd need something like 10 million Crab Nebulae to equal it in energy output.

NGC-1275 is also a strong radio and X-ray source. It's the brightest galaxy in the relatively nearby Perseus cluster of galaxies, and has a distance of about 160 million light-years. The filaments you see in the color picture spread to a total distance of about 45,000 light-years out from the nucleus. The nucleus emission at radio wavelengths is variable in strength, and its source has a size of only a few light-years diameter. The radiation this source gives off is about equal to 10^{11} suns — roughly the same as the whole of our Galaxy's output altogether.

When some other galaxies are examined by radio telescopes, great expansive areas of strong emission are detected out to tremendous distances. It's thought that somehow gas has been expelled from the active nucleus, and is making radio noise as it smashes through the intergalactic medium.

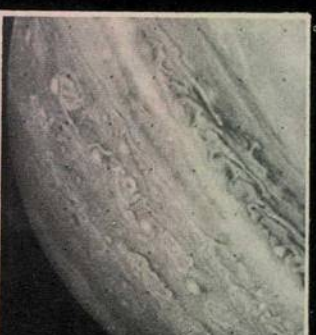
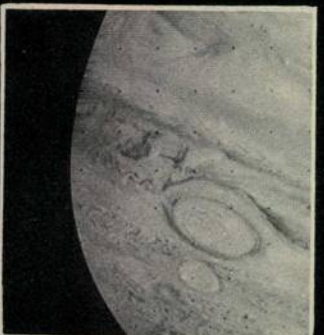
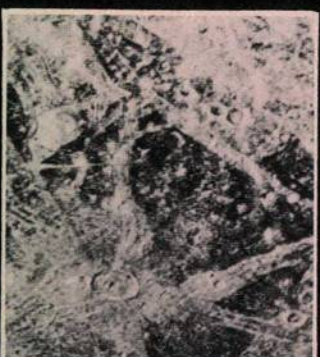
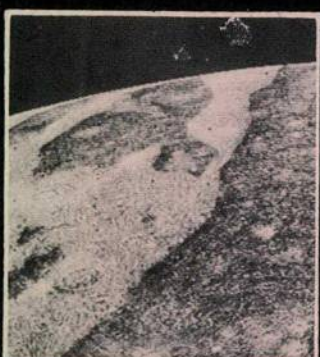
The prime problem facing astrophysicists is to account for this and other obviously compact, yet fantastically powerful, energy sources. The ubiquitous black hole, a favorite candidate of theoretical astrophysicists for high energy generation, may be the culprit though no one can yet point to more than one with much certainty. (The black hole provides energy by pulling matter down into it. Just before the material disappears into the black hole, it releases a gigantic flash of X-rays and other energy. The flash comes from the intense heat of the material as it's literally squeezed out of existence.) But the problem is that while theorists may well be satisfied with such a model, observational astronomers would like to have less ambiguous evidence for them than that found so far.

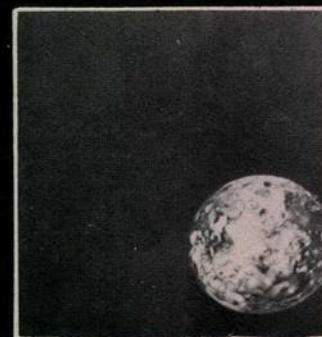
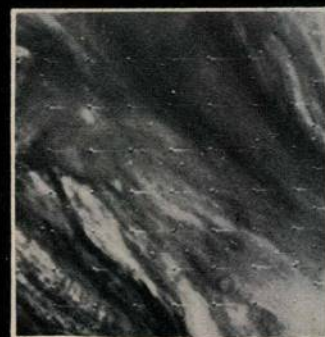
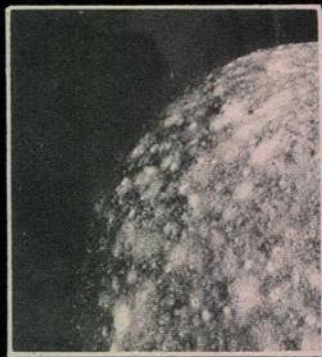
Here the matter stands at present. Clearly *something* is going on in these nuclei, but whether it's a passing phase that all galaxies go through, or is unique to some of them, no one yet knows. ☛



A Voyager Album

Voyager, more than any space mission before it, owes tribute to photography — imaging, as the scientists call it — from space. Ranger, Surveyor, Mercury, Gemini, Apollo, Mariner, Pioneer, and Viking — great missions of discovery — never revealed so much newness and never went so far beyond the known. On this and the following pages is an album of stunning black and white and a beautiful portfolio in color, pictures of new worlds revealed: Callisto and its basins, Jupiter's Red Spot, the Jovian ring, and the grooved and cratered plains of Ganymede.



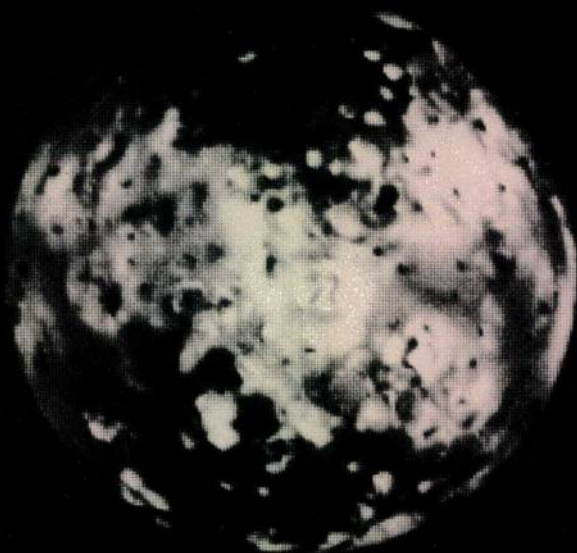




Jupiter's Ring



Amalthea



Io



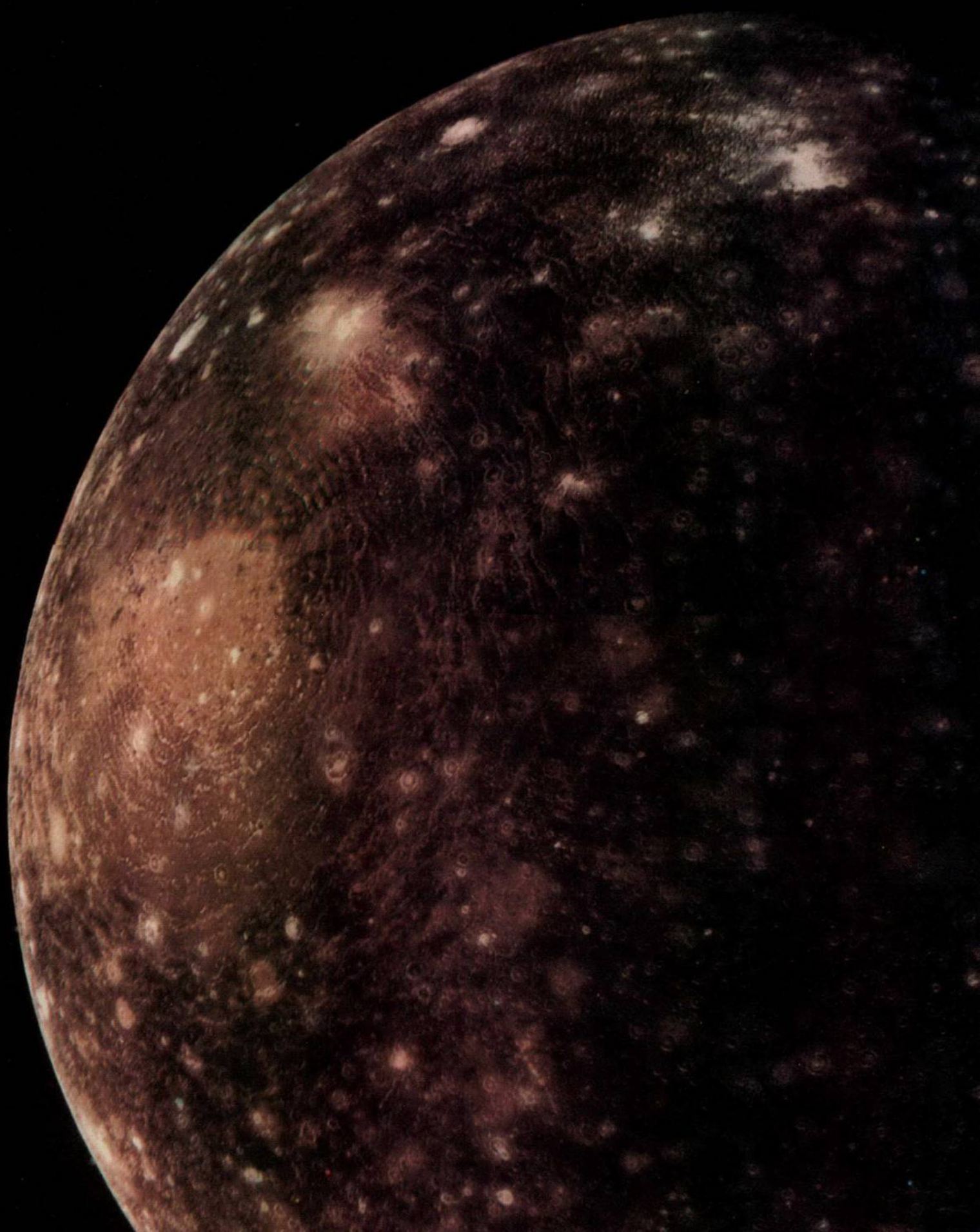
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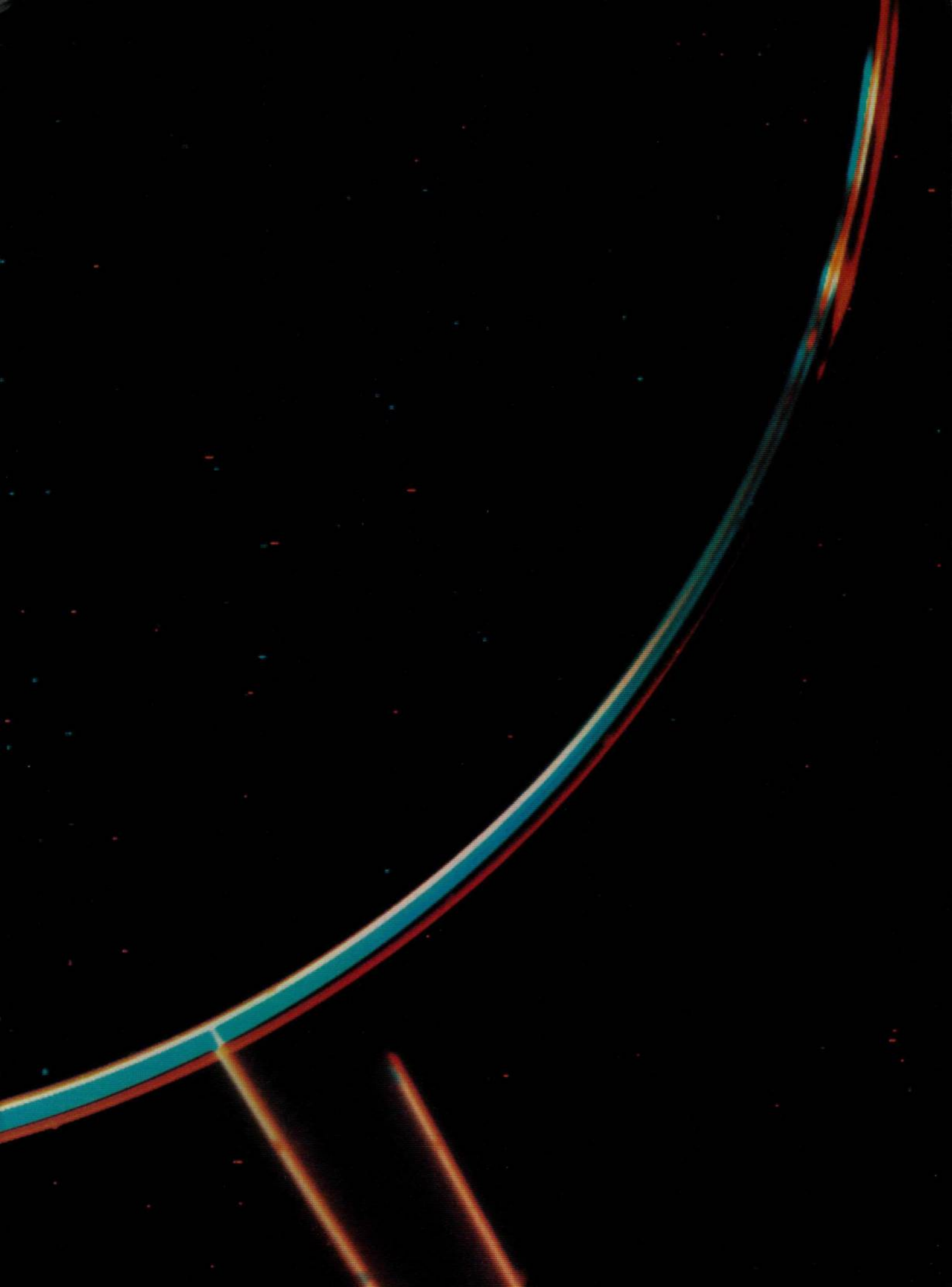
Ganymede



Callisto



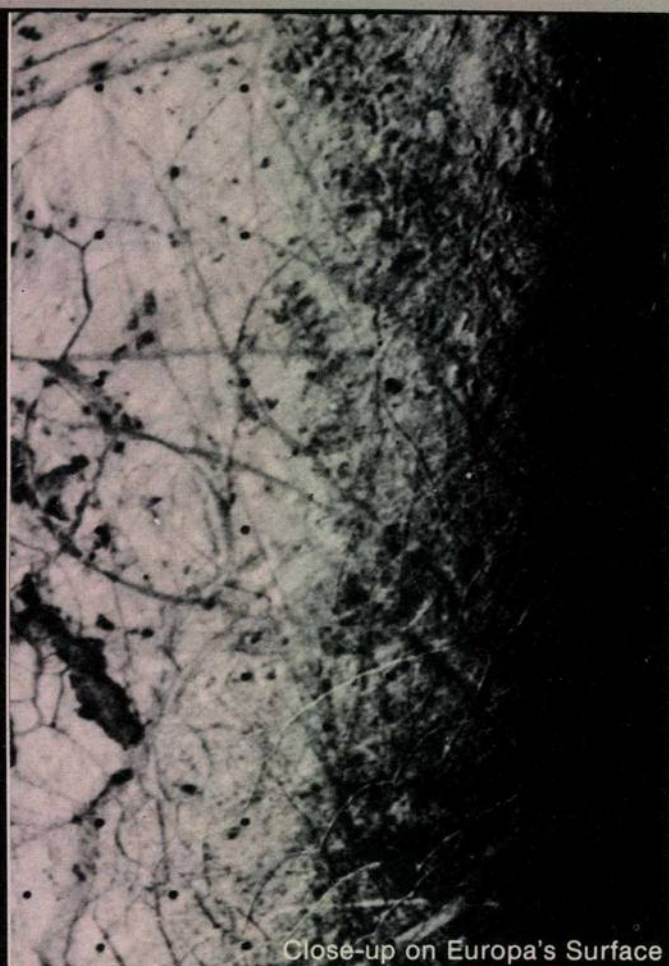




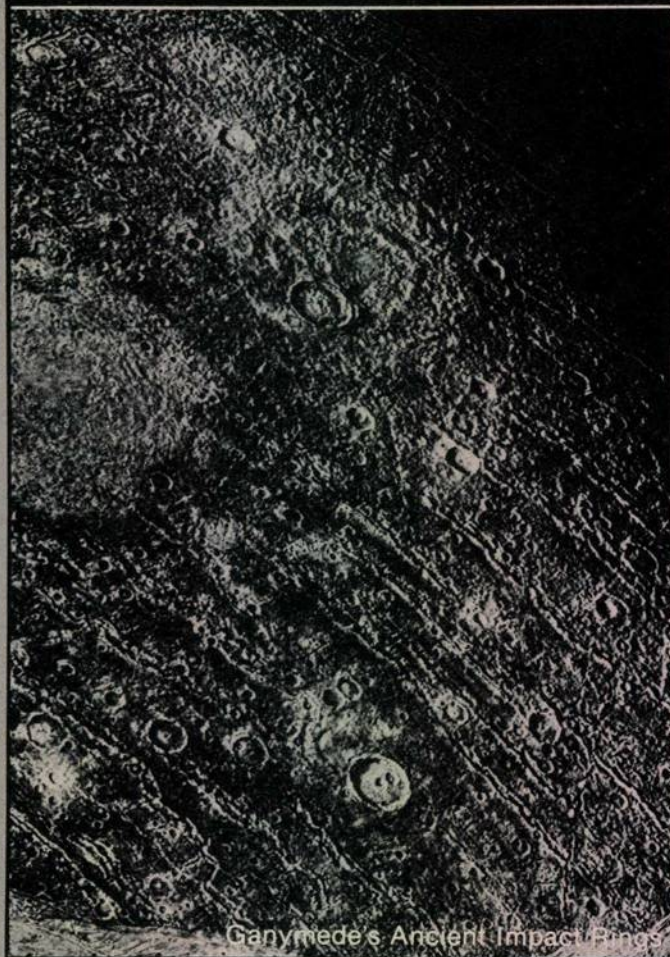




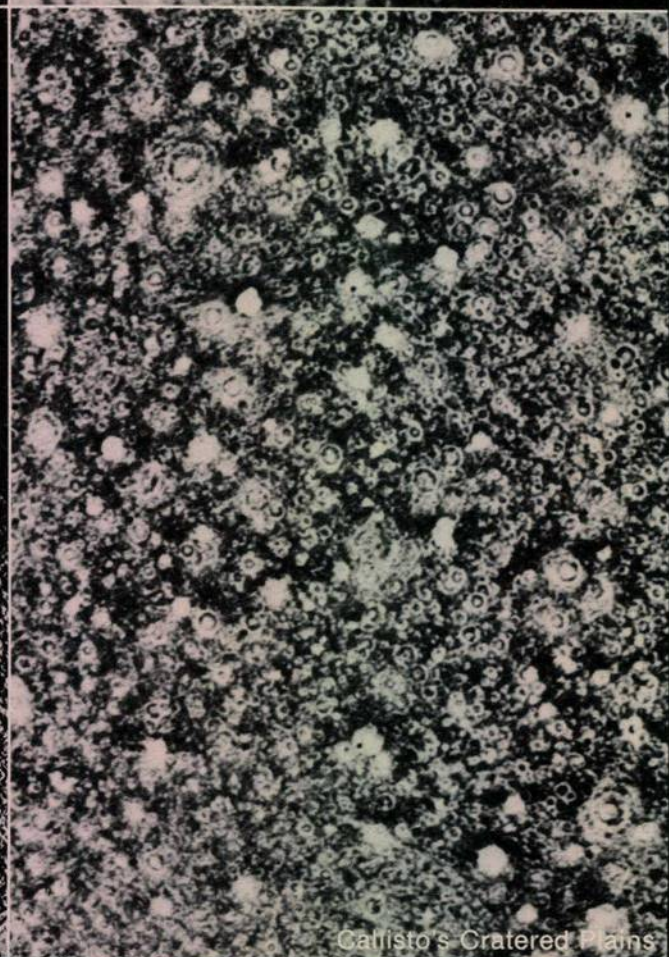
Two Volcanos on Io



Close-up on Europa's Surface



Ganymede's Ancient Impact Rings



Callisto's Cratered Plains

ASTRONOMY forum

A Personal Voyage to Jupiter

When humans voyage into space to explore the unknown, the work must be done by a representative few. What is found must then — somehow — be conveyed to the rest of the world in order that we all might share in their discoveries. It was my privilege, exciting indeed, to be a part of that group reporting the incredible story of the exploration of space.

The Jet Propulsion Laboratory in Pasadena, California lay at the focus of activity. There was a feeling of festivity about the entire lab. A busy place most of the time, it held a special excitement for the many employees and visitors during the Jovian encounter. Even the fountain in the main square was turned on to help pull the heat from the summer days. And the cafeteria, reminiscent of high school cafeterias everywhere, was opened special hours to accommodate the influx of visiting Voyager staff.

Before dawn on the morning of the encounter, the famous laboratory where the dream of this mission had begun was quiet and still. I sat on the steps in front of the von Kármán Auditorium to catch a breath of fresh air and watched the glowing orange of dawn lift to reveal a clear blue sky. Lost in thought about how far we had come, I barely noticed as the quiet of the early morning turned into the noisy sounds of automobiles with people arriving to start the busy day.

It was as though we ourselves were traveling through space and were looking through portholes at the planets as we passed by them.

The morning passed quickly, as the time of encounter drew near. The small rooms next to the auditorium became crowded. I began to see familiar faces and recognized names on the JPL security badges. I knew these people from books and television: Carl Sagan, Robert Heinlein, Ray Bradbury, even Gregory Peck and Tony Orlando! The last people to arrive were the project scientists, their reddened eyes revealing that they had probably been up studying the incoming data throughout the night.

The geologists, astronomers, and physicists had come before to tell us of their latest interpretations of the data from the spacecraft. This particular briefing, however, seemed more symbolic than informative, a rite of passage requiring ritual. The festivities were geared to impress; the words of the scientists expressed pride in the mission and in the progress of humankind.

On this important day, however, the major television networks were conspicuously absent. Why had they chosen to ignore Voyager's messages to Earth? Why were they not here on this milestone day in our reach into space? Part of the reason, perhaps, was the forecoming demise of Skylab. That errant vehicle was to fall, by unfortunate coincidence, on the very day of encounter. Scrap from the fallen space laboratory made the headlines that day; Voyager was nearly forgotten in the worry of the morning and the relief of the afternoon.

America, or at least its popular media, was more interested in the end of a single venture into Earth orbit than in humanity's hopeful beginnings as a traveler to other planets. This was an important step in our exploration of space. We were crossing the boundar-



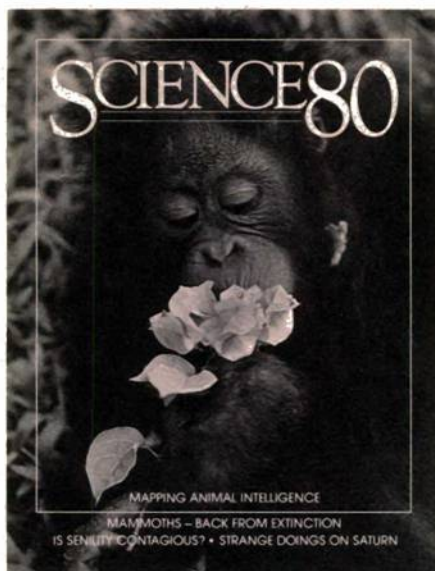
We laid claim to a particularly good monitor...

ies of the asteroid belt into the domain of the outer planets, full of mystery, with vast differences from our smaller, better explored inner planets. Yet this step was not considered important enough by the world's most popular communication medium: commercial television.

In spite of commercial TV's misjudgement, the mission was important to the public. Thanks to the efforts of the public television station in Los Angeles, KCET, many people, who otherwise would not have been able to, could share in the excitement. KCET's "Jupiter Watch," originally planned as a 5-minute nightly program during the week of encounter, was extended to many hours of quickly organized programming because of public request. Whatever reasons the commercial networks had for their limited coverage, they failed — utterly missed the chance — to bring their viewers a truly wonderful experience.

Meanwhile, those of us who had taken up temporary residence in the press rooms were having a great time. We laid claim to a particularly good monitor and watched the pictures evolve as they came in from Voyager. For most of that week we left our posts in front of the TV screen only for briefings, meals, and an occasional few hours of sleep. Once in a while, one of the project scientists would wander

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into our den of many questions. We pelted these poor sleepless creatures with so many questions that they usually retreated quickly.

The usually blasé and matter-of-fact press people had been caught up in the excitement of the event. We became travelers through the solar system. It was as though we ourselves were traveling through space and were looking through portholes at the planets as we passed by them. Each picture was more exciting than the last. There were shadows of rich craters. There were tremendous volcanic mountains. And there were the cracks and lines of Europa's amazingly flat surface.

For all of the strange and wonderful sights of the Galilean planets and their master Jove, the climax of the mission did not occur till we had passed the gas giant and Voyager turned to take its farewell photos of Jupiter's dark side. It was the evening after the day of encounter; most of the invited guests and celebrities had gone. Only a skeleton of the press remained. Voyager was programmed to look back and give us a parting view of Jupiter, silhouetted by the twilight of the faraway Sun.

As the scan lines descended down the face of the TV monitor, the round edge of the planet could be seen. The lightning effects and the aurorae we had expected were there. But, at the bottom of the picture, there were two thin lines. They went from the glow of the planet's limb to the corner of the screen: the first clear view of the rings of Jupiter ever seen from the Earth, an

unexpected gift from the little voyaging craft to its earthbound creators! Although the rings had been seen by Voyager 1, and had been speculated about before that, the surprise and joy of seeing them so clearly was certainly the peak of our second close look at the colorful planet.

I recently revisited the Jet Propulsion Laboratory. The press rooms are scrubbed and waxed and have once again become what they once were, a museum. The von Kármán Auditorium is cold and empty, and there is a work-a-day feeling about the campus-like lab. It was an exciting encounter. It gave us more than we had hoped for, and its rewards are quickly becoming reality. Dr. Bradford Smith of the University of Arizona summed it up for us: "We have seen into the dark outer reaches of the solar system into worlds that are so bizarre they even exceed the expectations of science fiction writers."

The first part of the adventure is over; it is time now to return to our Earthly existence and wait for the little Voyagers to reach the Saturn system. We have challenged the giants on their own territory, and dared them to keep secrets from us any longer. I somehow doubt that anything can ever be quite the same again.

Myra Weir
Costa Mesa, CA

Myra Weir is a physics and astronomy student currently involved in the remake of the "Jupiter" episode of KOCE-TV's "Project Universe" series.

FAR OUT — by Jove!

There, at last, was the celebrated image of Jupiter on the video monitor at JPL/NASA. A "live" picture — in real time.

But how real the time?

The picture left the jovian environment 51 minutes 48 seconds ago, at the precise moment when I had pressed the garage door opener in West Los Angeles to leave for Pasadena. It showed one of the unforgettable flyby scenes which Voyager 2 sent back to Earth over a distance of 575,942,000 miles. Even as I drove east along sunlit freeways, the 4½ million elements comprising the one teletpicture were streaming through the black void of interplanetary space at the rate of 115,000 electronic bits per second, to arrive in orderly sequence in Canberra, Australia on the other side of our planet where it was nighttime.

Though traveling at the speed of light (186,000 miles per second), it would take almost an hour before the giant dish "down under" could receive and relay the faint signal and send it

via earth satellite to California — from tomorrow to yesterday.

"Jupiter" was the caption in the top right hand corner of the television screen. Next to it were cryptic letters and numbers: MTIS VG2-2 R/T FILT. Bordering the picture was a gray-scale. Next came some graphs and then more scientific data in the secret language of the initiated and their machines.

"Press only" commanded the sign as you turned left into an area where rows and rows of tables with typewriters had been set up and many more television monitors, so that no one would miss even one telemetered digitized bit.

Correspondents from the national and international media were there: George Alexander of the *Los Angeles Times*, Tom O'Toole of the *Washington Post*. Wire service people came and went. J. Kelly Beatty from *Sky and Telescope* sat not far from Richard Berry of ASTRONOMY. Major TV networks had camera crews with



Press briefings: the latest audio-visual systems...

video-recording equipment wired into the ongoing television coverage. The spaghetti of coaxial cables snaked along the floor. Articulate video updates were given on the hour on closed circuit picture monitors, reporting and analyzing data which had arrived within the last sixty minutes.

At press briefings, learned scientists using the latest audio-visual systems, reviewed the most recent input. There Dr. Brad Smith, head of the Imaging Team, would intone gravely and unsmiling about sulphurous magma. Graphs would be projected on high-gain projection screens depicting the abundance of carbon — or the almost total absence of this element.

Informal background sessions were held, where vulcanism on the Galilean satellite Io was discussed and new theories were advanced.

It was always the same handful of persons who asked questions almost as if to flaunt their own expertise in one area or another rather than to shed new light overall. The answers, in turn, were always worded in the most guarded terms:

"Would anybody care to speculate on the possibility of the presence of igneous rock formations in the lower strata?" Pregnant pause.

"Well, let me put it this way: to the best of our knowledge at this point in time, and subject of course to verification as this mission proceeds, your assumption that igneous rock is present at some levels, is well taken. Of course Dr. So-and-so may have a different opinion; why don't we ask him?"



Dr. Brad Smith, head of the Voyager Imaging Team...

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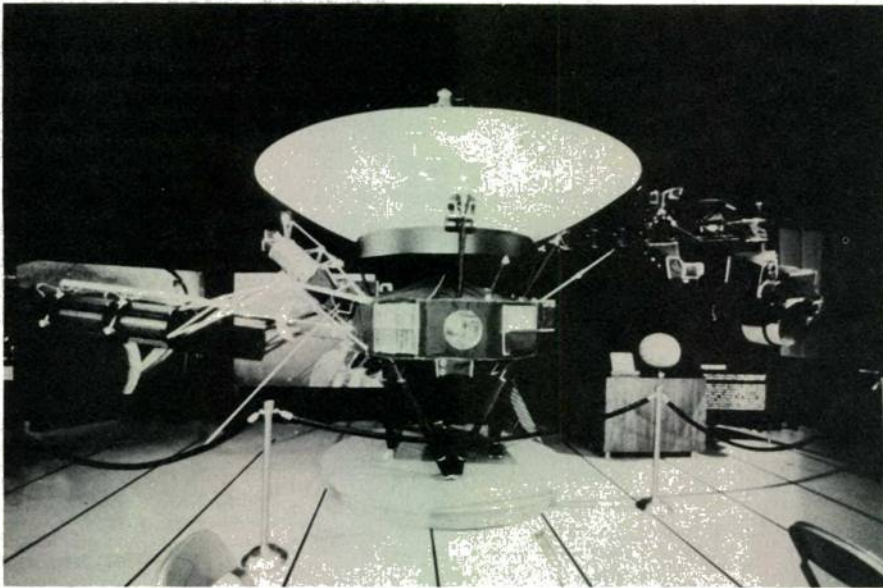
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FALL 1979 CATALOG



An exact copy of the spacecraft towers over all else in the auditorium...

"Frankly I'd hate to venture a guess on that one. My personal opinion, based on just the merest hunch would suggest that what we are seeing here is rather less basaltic than the first Voyager mission led us to believe. You'd have to put a shovel in it, so to speak, to be quite sure...ha ha."

At a time when specialization in science has reached the proportions which are nowhere more visible than in the various space programs, it may well be that the only persons who can truly understand the specialties are others working in the same special field. How then, can a science reporter — Ph.D. notwithstanding — comprehend what even specialists in the field are just beginning to grasp as first tenuous concepts?

What difference does the viscosity of the sulphurous magma on Io make to the public, when the overriding achievement lies in the voyage to this surprising and distant neighbor? The average reader or TV watcher has not cared until now and will hardly care hereafter. Fortunately there are interpreters among newsmen who can cut through the science-speak and translate the important first discoveries to ordinary mortals.

Still, the Voyager mission was overshadowed heavily by Skylab's impending crash. Now here was excitement: unpredictable dangers were lurking just eighty miles overhead. Somebody might actually get killed or hurt when the once proud craft fell back to Earth. "Let's run the Skylab story on page one and, oh yeah,

At a time when specialization in science has reached the proportions which are nowhere more visible than in the various space programs...

put that Jupiter thing on page three...."

Somebody might actually get killed or hurt...

There is so much to feel here, above and beyond the dramatic visual experience. As you look at the exact copy of the craft, which towers over all in the von Kármán auditorium, it's impossible not to remember that it has taken decades, and hundreds of thousands of our best artisans and the most gifted technicians, merely to create the vehicles which make it possible to carry experiments to the very edges of our solar system — and beyond. Let's not bury the brilliant efforts of an entire generation of contributors under scorching layers of silicate or freezing crusts of suspected ice.

And let's not forget Galileo.

When on January 7, 1610, Galileo

Galilei aimed his newly developed spyglass at the planet Jupiter, he set the stage for today's events. That night, in Padua, Italy, the Voyager programs were born — because it is precisely the same curiosity which prompted Galileo to study the "stars" which moved east and west of the familiar planet that underlies the efforts of our quest today.

For a fleeting moment contemplate the presence of the founder of modern experimental science. What if he walked into the press room at JPL/NASA now? Perhaps the presence of this elder statesman of science would introduce some humility into the proceedings and re-establish for all to see, how much modern science owes the giants of the past. Unlike today's scientists who are lionized by society, Galileo was in peril of his very life as he aroused the antagonism of the inquisition again and again with his bold new theories and findings.

Spectrometers remind me of Newton's contributions, telemetry brings Hertz, Marconi and Morse briefly to mind, and on and on it goes. There is hardly a discipline that is not represented in the venture, with some playing crucial roles.

It is tempting during such a brilliant performance of interplanetary magic, to focus all of your attention on the rabbit as soon as it has popped out of the hat. I certainly don't want to know just *how* it came out of the hat, but I feel that the performer putting on the show is truly a magician with many talents which I will never master or understand. I can witness his accomplished act and sense the endless hours of effort and training that went into its creation. In terms of human ambition and frustrations, I can identify with the magician even though I may not know his craft.

As for the rabbit, I will never understand it, unless I study veterin-



...still others of these priceless imaging products will be stored on their wide magnetic tapes, perhaps never to be looked at again.

any medicine or animal behavior. Like many others, I like to see the rabbit and perhaps stroke it a little.

Of the nearly one dozen Voyager science experiments, Imaging Science is, of course, the most highly visible. But there is so much more that is being learned, even as the dramatic pictures appear one after the other, line by parallel line: photopolarimetry, plasma studies, magnetometry, cosmic ray studies, low energy charged particle research, and other important new work. Not only will Jupiter and newly prominent Io be closely scrutinized, but Europa, Callisto, Amalthea and Ganymede.

A new image comes on the screen. It shows the shadow cast by Io on the swirling gaseous atmosphere of Jupiter. It's a showstealer, a likely candidate to become part of the portfolio of selected pictures which JPL/NASA will include in future press kits and releases. Perhaps this videograph — having just been received, relayed, computer enhanced, color-balanced, printed, and distributed — would, in turn, be reduced to

electronic components once again, to be re-transmitted, relayed by earth satellite, and received in Germany, sent to a photolab and from there rushed to platemakers and onto high speed presses to grace the cover of tomorrow morning's edition of the *Frankfurter Zeitung*.

Inevitably this picture will be seen again and again. Journals and picture magazines will use it and editors will be hardpressed to present these newest releases in new ways. The picture will be a part of editorials in science and astronomy publications, and may even turn up in the background of some department store telescope advertisement. This spectacular photo may be one in a set of six which a savings and loan association will "send free of charge to all savers with deposits of five hundred dollars or more." The credit — if it is given at all — will say merely "NASA photo."

There will be about 15,000 pictures in all. Some will be made into a motion picture to allow the study of volcanic action on Io, which will thus upstage the other Galilean satellites. Some will

be cursorily checked, others pored over. Yet still others of these priceless imaging products will be stored on their wide magnetic tapes, perhaps never to be looked at again.

Together with the data from the Pioneer missions, the Voyager tapes will have told us more about Jupiter and the Galilean moons than was known by humankind since the beginning of time.

As this is being written, our Voyagers hurtle outwards toward Saturn. This planet, because of the beauty and the grace of its rings, has captured the imagination of all who have ever seen it. Having disclosed the presence of a tenuous ring around Jupiter, the observant electronic eyes of our space probes should send back great images, containing not only new information, but possessing aesthetic beauty — the art of space.

These incredible views of Jupiter which were just unveiled and which remind me of Turner's flaming sunsets or the color rhapsodies of Matisse or Chagall, should make us look forward to the 1980 preview opening of the most magnificent of galleries: Saturnalia, courtesy of NASA.

Ben Mayer is a Los Angeles amateur astronomer known for heading PROBLICOM, a photographic search for novae (see "Blink for a Nova," ASTRONOMY, May 1978, page 34).

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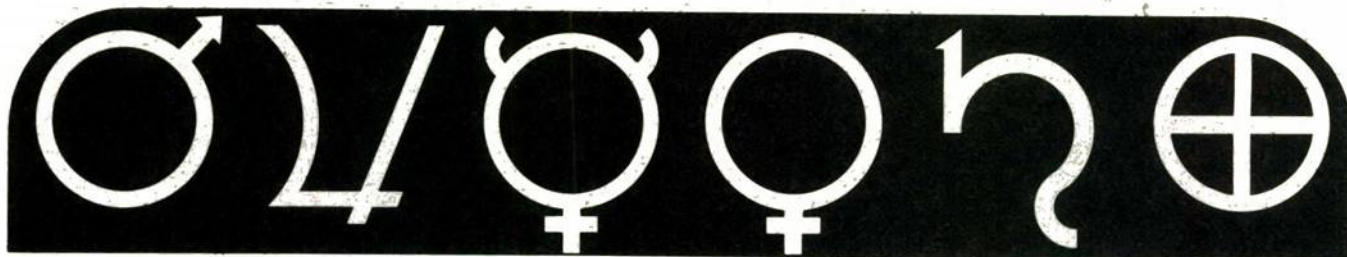
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SKY ALMANAC

A Plentiful Harvest of Planets

The month of October offers a variety of celestial events: the Moon has several conjunctions with planets and bright stars, Earth sees the saturnian rings edge-on, Mars passes through the Beehive Cluster, and there are two meteor showers. The crisp fall nights have returned and parade grand sights through the heavens for you.

Mercury

On the 29th of October, Mercury will reach greatest eastern elongation.

November Previews

- 4 Taurid meteors; full moon
- 6 Occultation of Aldebaran
- 8 Venus 2° north of Mercury
- 11 Last quarter moon
- 12 Moon — Mars conjunction
- 13 Moon — Jupiter conjunction
- 14 Uranus in conjunction with Sun
- Moon — Saturn conjunction
- 17 Leonid meteors
- 19 New moon; Mercury at inferior conjunction
- 23 Mercury at perihelion
- 26 First quarter moon

The Leonid meteor shower may provide a good display since the Moon, only 2 days before new, will not interfere much. The Taurids, occurring earlier, will probably not be all that strong: a full moon is the kiss-of-death for meteor displays.

Times of maximum elongation are the best for looking for this elusive planet, because only then is it relatively far from the Sun's blinding light. Yet not all elongations are equally favorable and this apparition is one of the worst of the year. Mercury will be 24° to the east of the Sun in the evening sky, but you won't see it very high above the horizon. On the 29th it'll be just 3.6° high in the west-southwest half an hour after sunset. Moreover, the planet's +0.1 magnitude is dim, considering the brightness of the surrounding sky.

This poor appearance for northern hemisphere observers happens because Mercury's orbit is angled at this time so that its declination is -22.5°. And because of its southerly position on the sky, the little planet never gets high enough over the horizon to be seen easily.

The next good apparition of Mercury comes early in December, when it'll be at greatest western elongation.

Venus

Though it's been in the evening sky for almost a month, Venus still is very hard to see. Like Mercury, Venus too has a large southern declination at present, and this is keeping it low for northern hemisphere watchers.

If you want to look for it, you'll do best toward the end of the month. Look for it about 3° high in the west-southwest half an hour after sundown. It will be at magnitude -3.4, but the brightness of the sky will prevent it from being very prominent. Mercury

at this time will be a short distance to the left of Venus at about the same altitude.

Moon

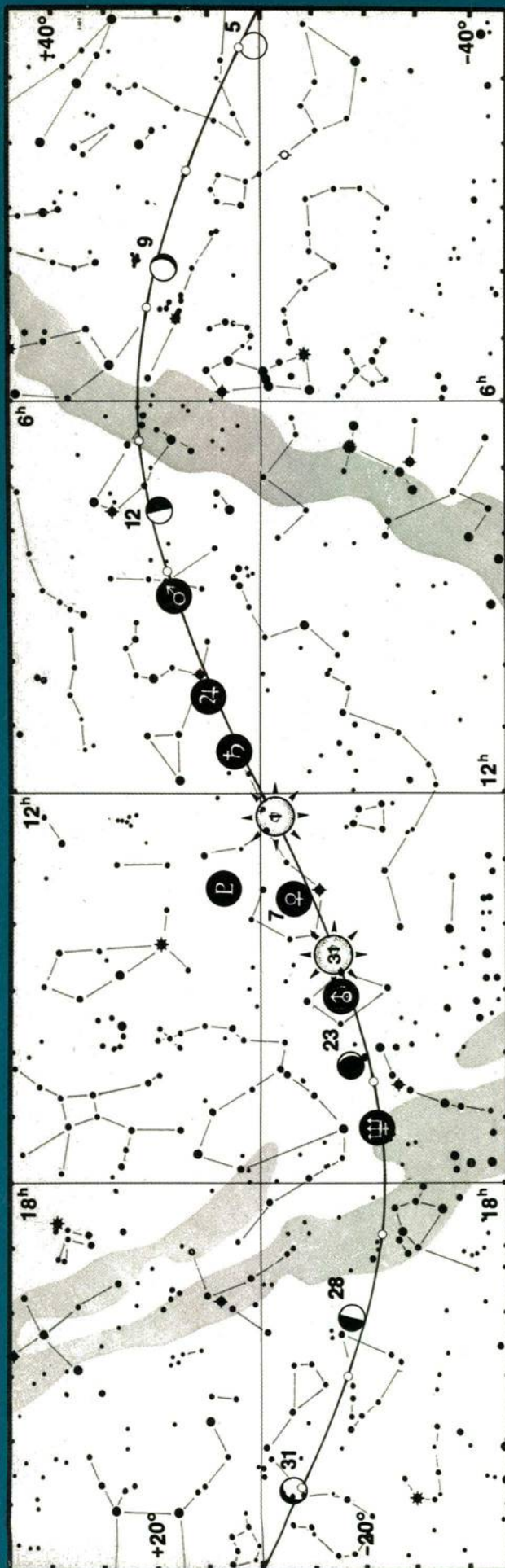
The full moon following the autumnal equinox is traditionally called the Harvest Moon. This year it falls on the 5th, and if you go out every clear night around sunset for a couple of days before and after this date, you'll see a full or nearly full moon rise at about the same time every night.

This comes about because the Moon's orbital path in fall is at a relatively flat angle to the horizon. So, as the Moon circles the Earth, its motion in orbit goes more towards moving the point of rising northwards than towards delaying the time of rise. Hence, you see a moon that keeps rising at about the same time, but which moves more and more to the north each day.

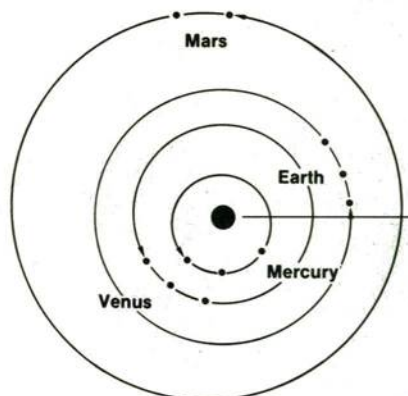
Mars

On the 6th of October, Mars passes through the Beehive Cluster in the constellation Cancer. At 22:39 UT, Mars will occult the 6.3 magnitude star Epsilon (ε) Cancri, but North American observers won't see the occultation since the planet and cluster won't have risen yet. Still, the approach and passage through the cluster will be an exciting and impressive spectacle to see. Any

Nelson Chow was in the wilderness of Algonquin Provincial Park, Ontario when he took this shot of Cygnus with a 50 mm lens riding piggyback on a 4½" reflector without a drive. The film was Ektachrome 400; the exposure 10 minutes.

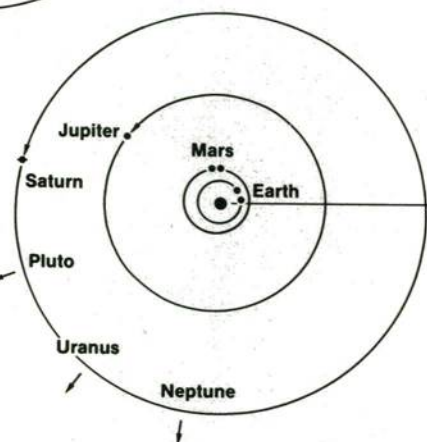


The Planets in Their Courses



The positions of Mercury, Venus, Earth, and Mars in their orbits are shown for the beginning, middle, and end of the month. (Mars for the beginning and end only.) The vernal equinox is the line at right.

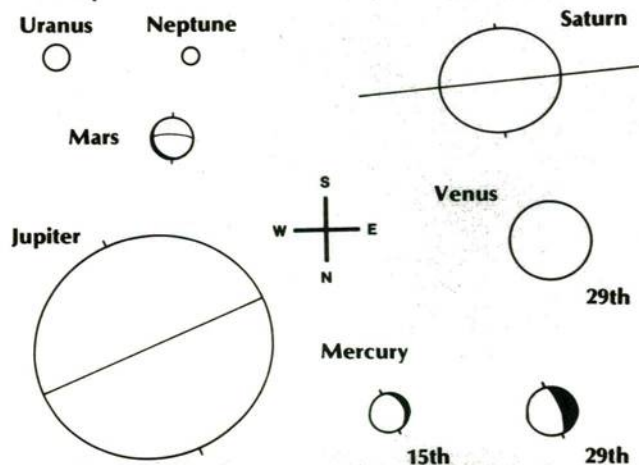
The orbits of Earth, Mars, Jupiter and Saturn are shown at right. Earth and Mars' positions are for the first and last of the month; Jupiter and Saturn for midmonth. The outermost planets' directions are indicated.



Positional Data

Planet	Date	R.A. (1979.8) Dec.		Mag.	Distance (AU)	
					Earth	from Sun
Mercury	♿ 10	14 ^h 06.1 ^m	-14°02.0'	-0.2	1.30	0.47
	20	14 ^h 59.8 ^m	-19°21.6'	-0.1	1.18	0.45
	30	15 ^h 47.4 ^m	-22°53.6'	+0.1	1.01	0.42
Venus	♀ 10	13 ^h 46.1 ^m	-10°08.1'	-3.4	1.67	0.72
	30	15 ^h 23.1 ^m	-18°34.6'	-3.3	1.61	0.73
Mars	♂ 15	8 ^h 58.0 ^m	18°32.0'	+1.3	1.63	1.59
Jupiter	♃ 15	10 ^h 20.7 ^m	11°12.1'	-1.4	5.97	5.36
Saturn	♄ 15	11 ^h 31.5 ^m	5°06.3'	+1.3	10.25	9.40
Uranus	♅ 15	15 ^h 08.4 ^m	-17°19.3'	6.1	19.58	18.71
Neptune	♆ 15	17 ^h 09.5 ^m	-21°33.7'	7.8	30.81	30.28
Pluto	♇ 15	13 ^h 34.5 ^m	8°00.1'	14.0	31.16	30.20

Telescope View





instrument from binoculars on up will suffice for watching it, and if you're set up for astrophotography, so much the better. Don't miss it.

Mars's apparent size will grow over the month of October from 5.4" of arc to 6.2". Over this time, it will also brighten by two-tenths of a magnitude. The planet's disk is about 90% lit and the phase effect mentioned last month has increased to just over half a second of arc. Earth's declination in the martian sky is about +18°, so the planet's southern hemisphere is now tipped away from us.

Jupiter

Jupiter, having passed just north of Regulus late in September, continues its southeastward path in Leo. On the morning of the 16th, a waning crescent Moon 5 days before new, will be close to Jupiter, providing a fine show.

Those with a telescope can peep into the jovian system about which the Voyagers have shown us so much. Dominating it, of course, is the mightiest planet of the solar system, with his swirling and tangled cloud belts that race around the planet.

Delicately colored hues predominate (the Voyager images were color-enhanced to help scientists discern subtle differences more easily), but even a small telescope and repeated observations will begin to reveal to you

the manifold structures of the jovian atmosphere.

Saturn

This month, the Earth makes the first of three passages through the plane of Saturn's ring system. Because this series of events is so special, there's a Gazer's Gazette on page 42 devoted entirely to it.

In the way of other events, there'll be a conjunction of the Moon and Saturn on the morning of the 18th. For North Americans, all you'll see is a conjunction, but for parts of the southern hemisphere, there's an occultation.

Saturn is in the morning sky, near the eastern border of Leo. The planet rises about 4 or 5 a.m. local time and will be at magnitude +1.3. Although Jupiter and Saturn are similar in size (Saturn's smaller by a little), Saturn's greater distance from the Sun makes it much dimmer. But when the rings are tilted more openly toward Earth, their reflectance almost makes up for Saturn's lesser brightness, bringing the planet's overall magnitude more in line with Jupiter's. Right now, with the rings seen edge-on, you can compare Jupiter and Saturn's brightness directly.

Uranus

Uranus, never very imposing, is now being severely encroached on by the

Lyra was well up in the northeastern sky when Jay M. Baker took its portrait. A 200 mm telephoto lens, 200 ASA film, and 15 seconds exposure netted him this photo. Now, where have we seen that foreground before...?

Universal Time

Astronomers the world over use an unambiguous system of time reckoning based on a 24 hour clock, called Universal Time (UT). Times given in Sky Almanac are in UT unless noted otherwise. To convert UT into your local daylight time, subtract the following number of hours for each time zone: EDT, 4; CDT, 5; MDT, 6; PDT, 7; Alaska and Hawaii, 9. For example, if an event is to happen at 03:00 hours UT on June 7, then the time in EDT would be 11 p.m. June 6. Likewise, 03:00 UT on Sept. 2 becomes, in PDT, 8 p.m. on Sept. 1.

Lunar Phases

Full moon: Oct. 5, at 19^h35^m UT, in Cetus-Pisces. Last quarter: Oct. 12, at 21^h24^m UT, in Gemini. New moon: Oct. 21, at 2^h23^m UT, in Virgo. First quarter: Oct. 29, at 4^h20^m, in Capricornus-Aquarius. Perigee: Oct. 4, at 15^h UT; apogee: Oct. 16, at 20^h UT.



M-104, known variously as the "Sombrero" or "Dust Lane" Galaxy, is an outlying member of the Virgo Cluster of Galaxies. Bill Iburg used a 14" Schmidt-Cassegrain, Ektachrome 400 (push-processed to 800 ASA), and a cold camera. The exposure, taken from Fremont Park, California, was 45 minutes.

Sun. Thirty minutes after sunset on October 1st, Uranus will be $12\frac{1}{2}^\circ$ high in the west-southwest (azimuth 235°). The planet is at magnitude 6.0 and shows a disk of only $3.5''$ of arc. By the end of the month, Uranus' elevation at the same time will be just half a degree!

Neptune

Like Uranus, Neptune too is nearing the Sun in the evening sky, though another month will pass before you'll effectively lose it to the twilight.

Neptune's apparent size is just under $2\frac{1}{2}$ seconds of arc, and its brightness is a dim +7.8. On the 15th of October, look for it 30 minutes after sunset at azimuth 214° (south-southwest) and 21° high.

Pluto

Pluto is in conjunction with the Sun on the 13th, at 2 hours UT, at which time it'll be 4.65 billion kilometers (2.88 billion miles) from Earth.

Meteors

October isn't a very plentiful month for meteor watching; there are two main showers, the Draconids (on the 10th) and the Orionids (on the 21st). The first of these will be greatly diminished by a Moon near last quarter which will flood the sky with light to drown out all except the brightest members, but the second shower may produce a great number of faint meteors.

The Draconids' peak activity comes at 14 hours UT on the 10th, mid-morning for North America, so observers here will have to catch them before the peak. The radiant point (the point on the sky where the meteors appear to come from) is near the head of Draco; although this area is circumpolar or nearly so for most of North America, the radiant point won't get very high in the sky until long after dawn. The number of meteors in this shower is greatly variable, depending as it does on the position of comet Giacobini-Zinner, a small periodic comet. This year's display should be small.

The Orionids, coming from the region of the sky around Betelgeuse, arrive at a more fortunate time: the Moon will be new and so the skies will stay dark all night. The Orionids arrive at a rate of about 25 per hour, but aren't usually very bright. However, the absence of the Moon means you might see a lot of the fainter members. Go out to a dark-sky site and see what you can spot. 🌠

October Satellites of Jupiter				12:00 UT			
1	40123	• • • • •		16	10243	• • • • •	
2	42031	• • • • •		17	24310	• • • • •	
3	42310	• • • • •		18	43201	• • • • •	
4	43021	• • • • •		19	43102	• • • • •	
5	43102	• • • • •		20	43201	• • • • •	
6	42301	• • • • •		21	42103	• • • • •	
7	42103	• • • • •		22	40213	• • • • •	
8	40123	• • • • •		23	41023	• • • • •	
9	01234	• • • • •		24	42301	• • • • •	
10	23104	• • • • •		25	320	• • • • •	
11	3014	• • • • •		26	31024	• • • • •	
12	31024	• • • • •		27	32014	• • • • •	
13	23014	• • • • •		28	21034	• • • • •	
14	21034	• • • • •		29	02134	• • • • •	
15	01243	• • • • •		30	10234	• • • • •	
				31	20314	• • • • •	

The four major satellites of Jupiter orbit the planet in periods ranging less than 2 days to 17 days. You'll see them change position from night to night. This table shows the approximate position of the moons each night. The column at the far left shows the date; the second column gives the names of the moons (Jupiter = 0, Io = 1, Europa = 2, Ganymede = 3, Callisto = 4). The third column shows the satellites' positions as they appear through an inverting telescope; south is at the top.

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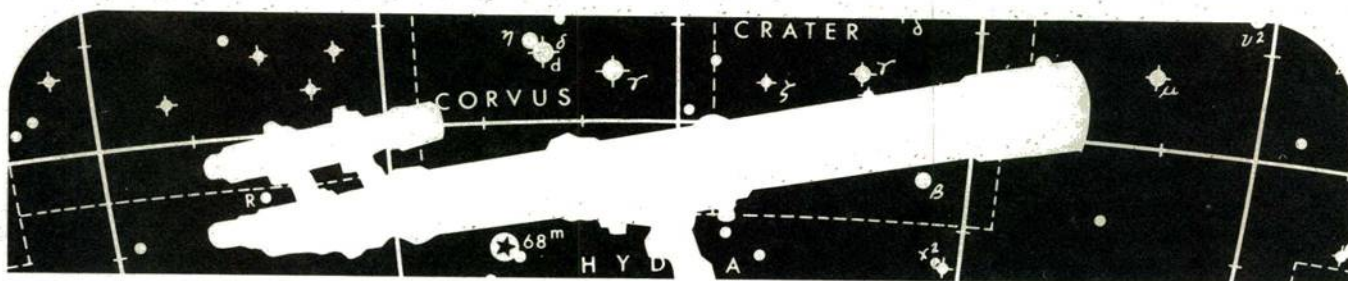
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EQUIPMENT ATLAS

The 1979 Buyer's Guide to Telescopes

You may be facing an important — and rather frightening — decision: which telescope to buy. You've thought about it for a while, perhaps done your share of naked-eye stargazing, become familiar with the constellations, and used your bird-watching binoculars to dip into the wonders the night sky offers. But now you realize that only with a telescope can you explore the beauty of the night sky fully; that somehow you're going to have to choose among all the types and brands of telescopes on the market and lay out some cold hard cash. It's a chilling prospect.

How can you wind up with a telescope that'll do what you want it to, one you can count on to become a faithful friend, to show you Saturn's rings, the jovian satellites, the face of the Moon, one that can time a stellar eclipse or take you into the realm of the galaxies? What type of telescope should it be; what size should it be; which of the claims you've read should you believe and which not?

For convenience, this article is divided into two parts: the first is about the problems you face in choosing a telescope, and the second part is about the telescopes themselves. The glossary on page 40 can help you with some of the technical terms you may not have seen before, and perhaps you'll recognize yourself or your friends in the Guide to Telescopes.

A Telescope is a Personal Thing

To get yourself ready to buy a telescope, you're going to have to do some thinking — thinking about what you want in a telescope. Buying a telescope is a very personal decision because there's no one "best kind" of telescope for all observers and all purposes. To some extent, you'll have to know — or guess — ahead of time what it is that you want to do with it,

what you want to see, where you're likely to use it, whether you'll be alone or with others, and you'll have to evaluate, realistically, how strong your interest in having a telescope is and how much money you want to spend for it. These things all depend on you, and not on the telescope.

You'll need to anticipate, at least in general terms, what your initial interests in observing will be because different types of telescopes are best suited to different kinds of observations. For example, if you want more than anything else to observe the markings on the planets, if splitting a close double star really appeals to you most, then bias your choice toward telescopes of long focal length and high optical quality, i.e., look at refractors and catadioptrics, not large-aperture RFT Newtonians. If you're unsure and you really don't want to tie yourself down, consider a general-purpose instrument such as a 6" Newtonian.

Spending the Right Amount

No one else can tell you how much you ought to spend on a telescope. But here are two rules to guide you through the worst of it: 1) don't spend any more than you can comfortably afford; and 2) be willing to spend enough to get a good telescope.

Time Enough Besides...

Another personal consideration is the amount of time you have for astronomy. It will surely influence how much you use the telescope once you've got it; so why not consider it in advance, at the time you're buying.

Astronomy takes time. If too much of that time is spent setting up and taking in the telescope, it won't get used. If you often work late, think about how you'll feel observing after you get home. How will your spouse react to your "nightly perambulations" and getting up before dawn to see

Mercury? Be sure that your choice of telescope makes sense in terms of the use you'll get out of it. Too many recruits to astronomy have found this out the hard way.

Consider, too, whether your garage could be used to store the telescope to save on set-up time if the scope is rather big, whether you would use it in the side yard or front, then (mentally) carry the telescope back and forth a few times. Carry it down the elevator (mentally) in your apartment building. Put it in the back seat of your car (mentally) to take to a star party.

Then remember you'll be doing all this carrying physically.

"Where" Counts Too...

Where you use a telescope matters. In the city especially, and in the suburbs around large cities, the sky is aglow with artificial light. No telescope, of any kind or size, can penetrate this glare for observing faint astronomical objects. Your suburban backyard, your apartment balcony, and your city rooftop are far from ideal sites for a telescope. If the Moon, planets, and a few bright stars constitute your "observable universe," then a well-made small refractor may be the perfect solution. Portability and storage are problems you'll have to reckon with, too.

On the other hand, if rural spaciousness or a dark-sky mountain retreat are available to you, portability and storage are still problematic, perhaps, but the sky offers many more possibilities. You may be willing to bring a short-focus 12" reflector out because of the fantastic observing it can provide; or depending on the size of your motorcycle, a pair of binoculars may be just the thing.

There's More Than One...

There's more than one telescope in

your life. If you're contemplating buying a telescope, keep in mind: "This is just the first one." If you've got any choice in the matter (and you do, because you're buying it), err on the small and simple side rather than the big and bulky side. A gentle introduction to the sky never hurt anybody; hours spent with a good pair of bird binoculars or a small reflector never turned anyone off astronomy. Rather than find yourself pondering the mysteries of setting circles and collimation (instead of looking through the telescope), try a small telescope first.

Of all the telescopes currently on the market, well-made 50 or 60 mm refractors, the ultra-portable RFTs, a few of the better spotting telescopes, and binoculars offer the best start. These instruments are all characterized by the availability of low powers (around 20x to 40x), convenience, portability, and prices under \$250. You use them by aiming them at what you want to look at; they're good because you're forced to learn the names of the stars and constellations and find your way around the sky.

If that's too humble for you, small and medium reflectors are "traditional" first telescopes. Four-inch f/10 reflectors, when well-mounted (look out for bad and shaky mounts!) are excellent performers. So are 6" f/8 reflectors, and they have considerable staying power — many observers use them happily for years. Their relatively low price makes them affordable, and they're still portable.

The second telescope can then be a much more ambitious instrument, purchased after you've gotten enough know-how and experience to get the most from a more sophisticated or larger instrument.

The Types of Telescopes

Different types of telescope have various characteristics that, for one reason or another, make them preferable for certain kinds of observations. Short focal-ratio telescopes (f/6 or lower), often called RFTs, are preferred by those who want to use low magnification for observing galaxies and nebulae, or searching for comets. Long focal-ratio telescopes (f/10 or higher), such as refractors or many catadioptrics, are the common choice of observers who want high magnification for lunar, planetary, or double star observing. That does not mean that either kind of telescope cannot be used for the other purpose, but only that each provides the greatest convenience for its own type of observation.

Today, the varieties of telescopes on the market have increased over what was available only a few years ago. There is now more choice, and a wider

range of price, than ever before. Large telescopes are far more common than they were in the past, and beginners with modest aspirations may be urged to buy a bigger instrument than they would have dreamed about a decade or more ago. Also, the new types offer convenience and portability not available previously. Let's look at the several types of telescopes and discuss the merits and deficiencies of each.

Small Refractors

Refractors with 50 mm, 60 mm, and 75 mm (3-inch) aperture are considered "small." These have been the classic beginner's telescope for at least 150 years, and for good reason: they give very good images and are quite portable. With focal ratios around f/15, ordinary eyepieces give a low magnification of around 40x (just right for general views of the Moon) and they have an upper limit of about 150x, suitable for general views of the planets. They don't offer much light grasp, but are generally sufficient for finding many of the objects on Messier's list of deep-sky objects.

Inexpensive small refractors have often been poorly mounted (whether equatorial or alt-azimuth) and the mounting has been the instrument's downfall. Look for a *solid* mounting when you look for a small refractor; if you find it, you can be sure the optics will be good.

In the United States, most small refractors have been imported from Japan, but the slippage of the dollar against the yen has raised the price of imports to the point where American-made small refractors have appeared on the market.

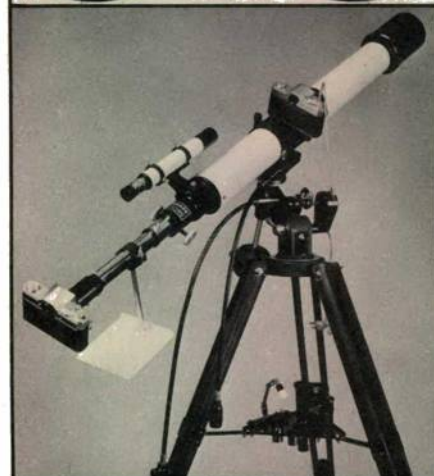
Medium-Size Refractors

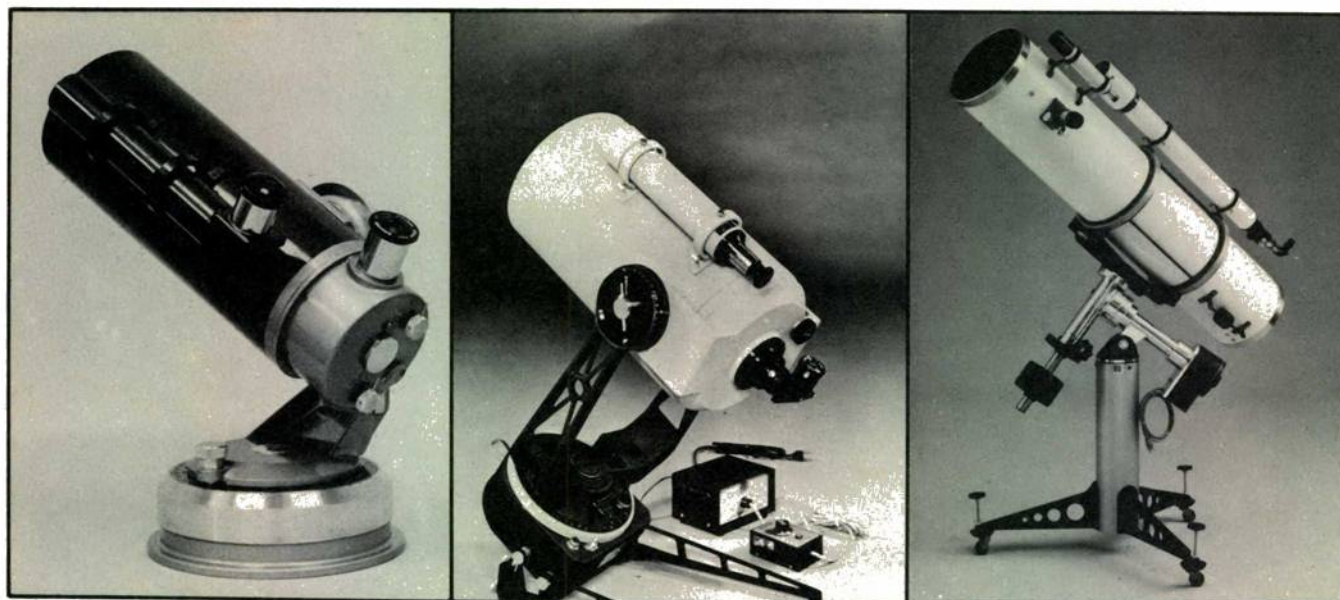
Four to six-inch refractors are considered medium; bigger ones are considered large. A 4-inch refractor of normal focal ratio (f/15) is about five feet long, and a 6-inch is eight feet long; you can see why the term large is applied to anything bigger! When it comes to detailed views of the Moon, planets, and double stars, medium-size refractors often outperform considerably larger reflectors and catadioptric instruments. Six-inchers offer up to 300x with crisp sharp images on nights when the seeing is good. They have only the light grasp of their aperture, however, and don't offer anything special for deep-sky observation.

Ready-made refractors are quite expensive for their aperture, in part because the length of the tube puts severe demands on the mounting. The lenses are not overly expensive, and the do-it-yourselfer looking for a fairly unusual telescope might well consider building a medium-size refractor.

Small Reflectors

Three and four-inch aperture reflectors are often sold as children's





toys. These telescopes are usually not worth the low price paid for them, because they quickly convince the child that astronomy isn't worth it.

A good 4-inch reflector is a serious telescope. If mounted on a solid mounting and used with good eyepieces, this aperture is sufficient to show the cloud bands of Jupiter, the rings of Saturn, and plenty of nebulae and star clusters. 200x is not excessive magnification on good nights.

However, there are plenty of very poor 4-inch reflectors on the market. Once again, the mounting is a good guide to the optical quality: look for good finish, heavy metal parts — preferably castings — and an

adequate tripod or pedestal base.

You'll find short focus RFT reflectors discussed under the heading "Newtonian RFTs."

Medium-Size Newtonian Reflectors

More 6 and 8-inch reflectors have been made at home than any other kind of telescope; in this country these have been the classic beginner's reflectors since the 1920s. A 6-inch reflector provides enough resolution and light grasp to keep an enthusiastic observer going happily for many years; an 8-inch is just that much better. Almost all of these telescopes are Newtonian reflectors, that is, they employ a paraboloidal primary mirror at the bottom of the tube to bounce the

light to a focus and a little mirror near the front to bring the light out the side of the tube near the front.

Most 6" Newtonian reflectors have a focal length around 48 inches (focal ratio about f/8) although shorter focal lengths are becoming more common because they are more compact. Six-inch f/8 and 8-inch f/6 reflectors have tubes about four feet long with a 7 and 9-inch diameter, respectively. Typically, the lowest magnification is about 40x, and the highest is around 250x. When made with a focal ratio of f/5 or smaller, Newtonian reflectors are often called RFTs (which stands for "Richest Field Telescope"). All this means is that with ordinary eyepieces, you can use low magnification to get a bright image for viewing nebulae and galaxies, and because of the short tube, the telescope is unusually compact.

Sometimes the focal length is extra long, such as f/10, giving higher magnification with ordinary eyepieces, and making the tube somewhat longer than normal. Because 6-inch f/10 mirrors need not be paraboloidal, they are quite inexpensive, a good choice for the do-it-yourselfer with limited funds.

Large Newtonian Reflectors

Mirrors larger than 12-inch qualify a Newtonian as "large," leaving the 10-inch telescopes in a nomenclatural no-man's-land. A 12-inch reflector is capable of superb and detailed views of the Moon and planets, and has excellent light grasp for nebulae and faint star clusters. Because the optics must settle down to air temperature before best performance is obtained, large reflectors are more temperamental than smaller reflectors.

For the past 30 years or so, 12 to 16-inch Newtonian reflectors have been the usual limit of commercial (as well as homemade) telescopes. Many a 12-inch Newtonian has served for years in

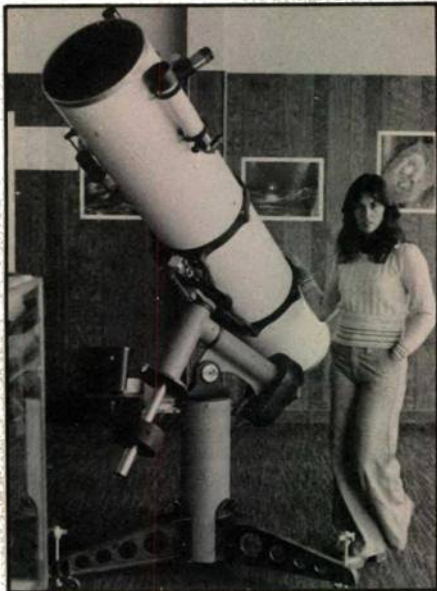
Buying That First Small Telescope

Your first telescope, even if small, should nonetheless be a *good* one. If the telescope is to be a gift for a child, be doubly careful: remember a telescope is not a toy and a good one will not be found in a toy store. Nor should you rush down to the local discount store and buy just any long white tube on a tall thin tripod sitting high on a shelf covered with dust. Look around in different stores. Seek a telescope with solid support, carefully made parts, large screws and bolts (this is often a tip-off: on good equipment, the incidentals are well-made), coated lenses (you'll see bluish or yellow reflections in them), and a 1¼-inch diameter eyepiece tube.

Insist on testing the telescope outdoors with a low power eyepiece. If the image of distant objects is *not* bright and clear (if you have any hesitation about whether it is, it isn't), if it shows

colored fringes around bright objects, if it turns out to be shaky when you tap on the tube, *don't buy it*. If it passes the low power test, try it at high power. At high power the image will be rather dark, but is it sharp and free of spurious colors? Is it easy to work the focuser? Does it shake badly? In any case, with a retail store, get return privileges in writing on the sales slip — then you're protected.

Expect to pay *at least* \$150 for a good 4-inch reflector and \$200 for a 60 mm refractor (summer 1979 prices), and be willing to pay more. If no local stores carry telescopes, you can buy a telescope by mail with reasonable confidence — with national mail-order houses, the greatest danger is that you'll order a company's bottom-of-the-line that's not up to the standards of the rest of their equipment.



an amateur society's observatory.

Large Newtonians, if carefully designed, can be termed "portable" instruments, especially if the focal ratio is kept fairly low. However, at best, a 12-inch $f/7$ telescope must be 14 inches in diameter and seven feet long — a bit on the large side for a compact car. The eyepiece end also tends to get far off the ground, and a stepladder becomes an "observing accessory." Once out under dark skies, however, they prove the worth of a large aperture.

Cassegrain Reflectors

Cassegrain reflectors are becoming less common today because of competition from catadioptric telescopes offering similar characteristics. Cassegrains employ a short-focus primary mirror and a convex secondary mirror to form an image conveniently located behind the primary mirror. With a typical focal ratio of $f/16$, they give a high magnification with ordinary eyepieces.

Newtonian RFTs

Newtonian reflectors made with a mirror of shorter focal ratio than $f/5$ are often called RFTs. These instruments provide lower magnification (and brighter images) with ordinary eyepieces than longer focus telescopes do, making them good for nebulae and galaxies. Because of their short focal length, they are more compact than other Newtonians of that aperture. Used with a high power eyepiece, an RFT will give you roughly the same magnification and performance any other telescope of the same aperture can provide.

Small RFTs can be made very easy-to-use and portable; well-made instruments of 4-inch aperture are good telescopes for beginners. The range of useful magnification is roughly 15x to 80x, suitable for the Moon and planets as well as deep-sky

A Guide to Telescopists

The Connoisseur

You insist on every capability in the book — and then some. You demand nothing but the best: the finest optics, top-grade components throughout, and you'll order every accessory available to add to your "system." You'd be interested in doing some research at the observatory you're thinking about putting in the mountains. In short, you want the ultimate telescope — at any cost.
First Choice: large catadioptric
Second Choice: large (18"+) custom reflector

The Functionalist

You've always wanted a truly fine telescope so that you could explore the wonders of the universe from your back yard. You want a telescope that will still do everything you want, one that's easy to use and reliable, especially if your interest deepens in the future. But then again, you don't want to spend a lot of money!
First Choice: 6" Newtonian
Second Choice: 8" Newtonian
Third Choice: small catadioptric

The Traveler

You like to travel, and you'd like to take it with you — into the mountains, out to the desert — but of course you prefer to travel light. You're looking for a telescope that's free of hassles, lightweight, and portable so that you can explore the wonders of the skies — galaxies, nebulae, endless realms of stars, from beside your campfire.
First Choice: large binoculars
Second Choice: ultra-portable RFT
Third Choice: a catadioptric

The "Playboy"

You'd like a telescope that'll bring you and your camera close to the action — at rallies, races, sports events — but at night becomes a portable observatory, delivering crisp images with flawless definition. You'd like it to be a fine instrument: one that's good-looking too, with superb machining, and finished beautifully so it can sit on display when you're not using it.
First Choice: small Maksutov catadioptric
Second Choice: medium catadioptric
Third Choice: 3" to 5" refractor

The Off-the-Shelfer

You like equipment that looks after itself — and your telescope should be no exception. You're after convenience so you can devote all your attention to observation and forget about the telescope. But you're not willing to lose any of the image quality

that fine optics can deliver. Versatility is important, too, because you're going to get into astrophotography and you want a telescope you can hook your camera right onto and start photographing.

First Choice: medium-size catadioptric

The Deep-Sky Wanderer

Your mind is made up: you want to search out the nebulae and explore the galaxies. You're willing — in fact, eager — to make special trips out of the city to dark skies where you can work right down to the magnitude limit of your telescope. You want all the light you can get. And maybe in a few years you'd like to try your hand at astrophotography, too — deep-sky astrophotography of course!
First Choice: large Newtonian RFT
Second Choice: large catadioptric

The Refractor Buff

You've heard all the arguments one way and another about refractors versus reflectors, but you just plain like refracting telescopes. You appreciate perfect images and a crisp, sharp, well-defined field. You like the elegance of the long tube and feel the image quality makes up for the relatively small aperture.
First Choice: 4" refractor
Second Choice: 6" refractor

The Careful Dilettante

You get interested in a lot of things — and astronomy is just one of them. Before spending a lot, you'd like to "stick your toe in the water" by getting a nice little telescope to check out what's going on up there. And if it just doesn't turn you on, then the telescope would make a good gift for your niece on her next birthday.
First Choice: 4" $f/10$ reflector
Second Choice: small well-made refractor
Third Choice: spotting telescope

The Do-It-Yourselfer

You built your own go-kart when you were a kid and finished a digital clock last weekend. You like mechanisms, and you hate to pay high prices for something you could probably make better yourself. You want a telescope and a really good one: you plan to buy the tricky parts, make the easy ones, and save a bit of cash on the project.
First Choice: 10" Newtonian (homemade)
Second Choice: 6" refractor (homemade)
Third Choice: 8" Cassegrain (homemade)

objects. A number of unusual-looking mounts and take-down designs are now available. The low magnification of these telescopes also means they function well in place of large

binoculars and make nice second telescopes.

Medium and large RFTs are desirable for deep-sky photography because the "fast" optics permit

shorter exposures; however, unless the eyepiece holder is unusually low and large, it may not be easy to adapt them for use with a camera.

Glossary

Alt-Azimuth Mount A type of mounting that lets the telescope be pointed in a simple up-down and left-right fashion.

Aperture The diameter of a telescope's light-gathering lens or mirror, usually measured in inches or millimeters. Large aperture telescopes collect more light and show fainter stars than small aperture telescopes do.

Catadioptric A telescope that uses both mirrors and lenses to form its image.

Coated This term means that a very thin layer, or coating, has been applied to a lens to reduce extraneous reflections. Coated optics give crisper images.

Equatorial Mount A type of mounting that allows the telescope to swing parallel to the Earth's rotation, making tracking of stars a bit easier.

Eyepiece The small lens "that you look into." They have different focal lengths to give different magnifications and are interchangeable. You will probably want several eyepieces to give a range of magnifications.

Focal Length In simple telescopes, the distance between the light-gathering lens or mirror and the place where the light comes to form an image.

Focal Ratio This is just the focal length divided by the aperture of the telescope. It tells you how long or short the telescope is. A low focal ratio usually means a stubby telescope.

Magnification The increase in the angle an object fills when you look into the telescope. You can find the magnification of a telescope by dividing the focal length of the telescope by the focal length of its eyepiece. Different eyepieces give different magnifications.

Maksutov A type of catadioptric telescope that uses a mirror, a thick deeply-curved correcting lens, and a small mirror to form its image.

Newtonian A telescope that uses two mirrors to gather and focus light from a star; one is a large concave mirror at the bottom of the tube, the other a small mirror that bounces the light out the side of the tube to an eyepiece.

Objective Another name for the main, or primary, lens or mirror in a telescope.

Reflector A telescope that uses a mirror to form its image. The mirror is exceedingly accurately shaped to a tolerance of a few millionths of an inch.

Refractor A telescope that uses a precision lens, nowadays always an "achromatic" lens free of color errors, to form its image.

Schmidt-Cassegrain A type of telescope that uses a mirror, a thin correcting lens, and a small mirror to form its image.

Small Maksutov Catadioptrics

Small Maksutovs are those from 60 mm aperture through approximately 100 mm (4-inch) aperture. The Maksutov optical system can be very compact; the complete telescopes are sometimes less than a foot long, yet they provide extremely high grade images. Useful magnifications range from 40x to approximately 200x. The correcting lens closes the tube so that the optical system, given the same treatment, remains cleaner (less dust creeps in) than the optical system of a Newtonian.

Their very size makes these telescopes useful as telephoto lenses for cameras; indeed, you'll find some of the manufacturers advertise them as lenses in camera magazines. Attached to a solid tripod or manufacturer's equatorial mount, they double as telescopes.

Their compactness makes these instruments especially suitable for city-bound stargazers because storage on a shelf in the closet is entirely feasible, yet they provide excellent definition and the full resolution their aperture can provide. They are expensive for their aperture and don't offer anything exceptional in light-gathering ability.

Medium and Large Maksutov Catadioptrics

Exactly where small and medium separate is a point of no importance in telescope design, but this distinction is a big one when it comes to owner pride. Six-inch and larger Maksutov telescopes are definitely in the medium class.

The performance of these instruments is refractor-like in quality; the closed tube eliminates most air currents and the images are beautiful. The tube, like those of the small Maksutovs, is short, and they are therefore compact and portable. It's generally easy to attach a camera to them with adaptors sold by the manufacturers.

For deep-sky observing, these instruments have no optical advantage over a Newtonian reflector of the same aperture. However, they can be used from a sitting position.

Large Maksutov instruments have been built by amateur telescope makers for several decades, but they have only recently appeared on the commercial market. They are expensive.

Small and Medium Schmidt Catadioptrics

Schmidt-Cassegrain telescopes of 5, 6, and 8-inch aperture have become very popular because of their portability, performance, and the ease of attaching photographic accessories to them. While very common now, a decade ago there were virtually none, and the few in existence were very expensive. The breakthrough lay in

mass-production methods for the complexly-shaped precision Schmidt correcting lens at the front of the tube.

These instruments are very short for their aperture, resulting in excellent portability and good storage. They provide, in common with some of the Maksutov instruments, an excellent and simple means of attaching a 35 mm camera for astrophotography and are sometimes used for extreme telephoto effects by photographers. Those on the market today can be used as alt-azimuth or equatorial instruments depending on whether the base of the telescope is tipped toward the celestial pole.

Large Schmidt Catadioptrics

Large Schmidt catadioptrics offer more aperture in less space than any telescope available before. Highly suitable for small observatories, the only real alternatives are large Newtonians and Cassegrains, both more bulky though considerably less expensive if homemade.

Spotting Telescopes

A few of the spotting telescopes on the market are suitable for getting started in astronomy, though they seldom have enough aperture and cost nearly as much as telescopes suitable for astronomical observation. Look for good mechanical construction and you can generally count on good optics.

Binoculars

Binoculars are good for getting a start in astronomy. 7 x 50s are the most common and versatile binocular. They are good for sweeping the sky in search of clusters and nebulae, watching bright variable stars, and seeing the largest features on the Moon. Large binoculars, such as 12 x 80s, are prized by deep-sky observers for picking out the larger nebulae or bagging lots of their favorite objects in a short time. Such binoculars are very portable and surprisingly lightweight. Before buying big binoculars, weigh the cost against the price of a good small telescope which in the long run will be better for astronomy. ☛

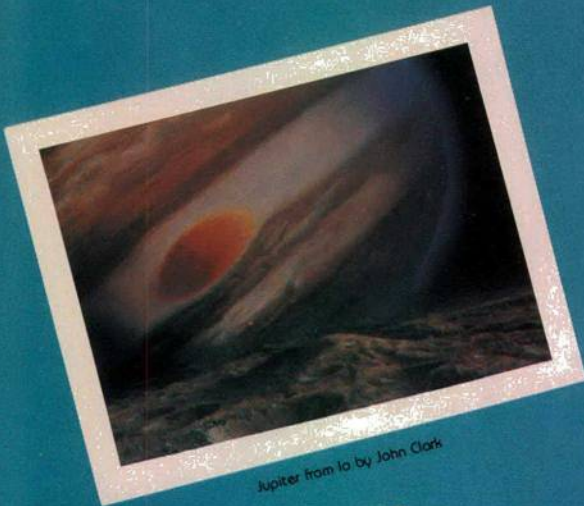
The author's bias: The author is a cross between a do-it-yourselfer and a deep-sky-wanderer. He has built and used extensively a 6-inch f/7 Newtonian, a 6-inch RFT, an 8-inch f/10 Newtonian, an 8-inch Cassegrain, and a 12-inch f/7 Newtonian which he used in an observatory in various back yards for many years. He is currently working on a bigger telescope.

He has used Maksutovs, Schmidt-Cassegrains, a small refractor, & several large refractors. Last winter, with many feet of snow in Milwaukee, his favorite telescopes were a 4-inch RFT and a 4-inch f/10 Newtonian because they were so easy to set up and use.

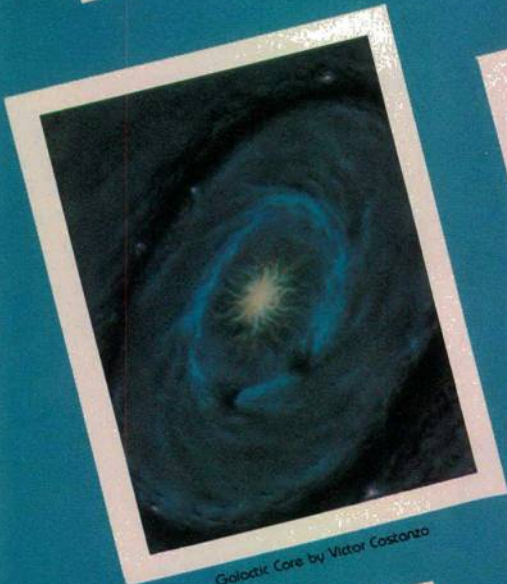
— Richard Berry

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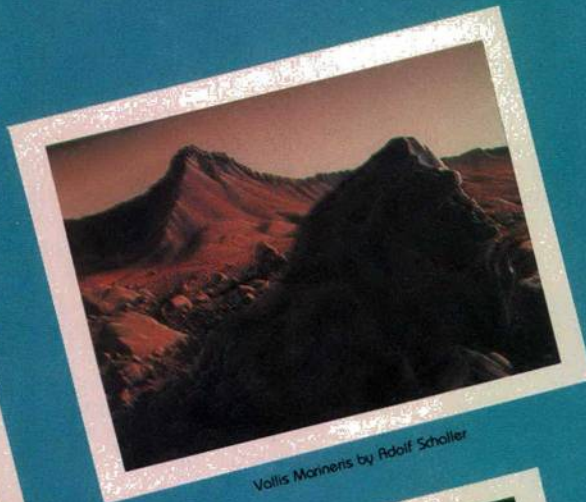
The guys in the stock room have been stumbling over these for months, and now that we've got new posters coming in, we really need the room! Buy them now, because once they're gone, you'll never see them again!



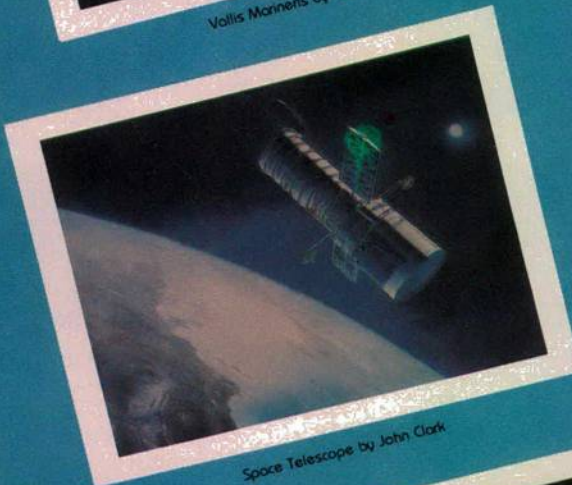
Jupiter from Io by John Clark



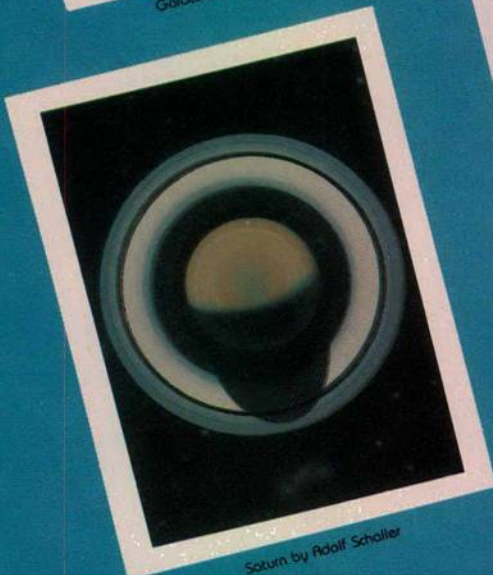
Galactic Core by Victor Costanzo



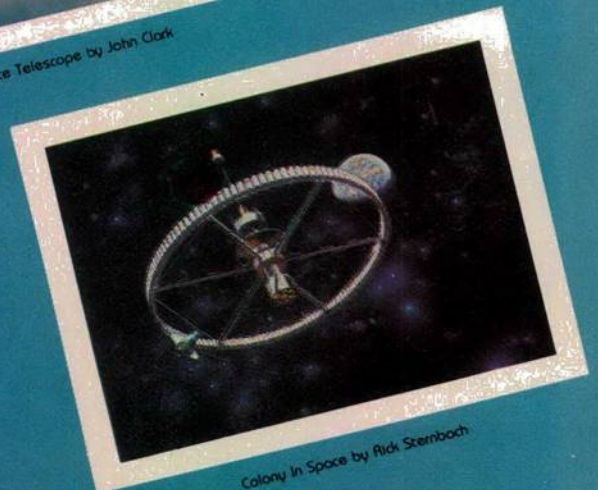
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Space Telescope by John Clark



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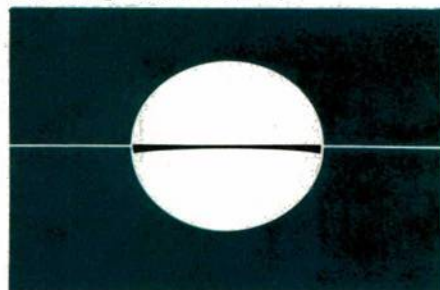
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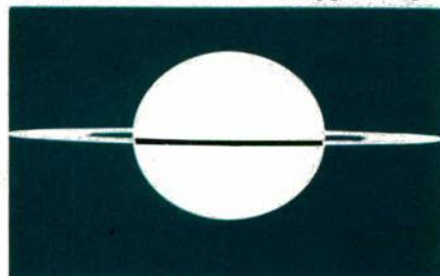
Saturn's Vanishing Rings

On the 27th of October, an astronomical event will take place that hasn't been seen since 1966: Saturn's ring system will appear edge-on and the rings will vanish from sight. Nor is the event a one-time affair, for there will actually be three separate passages through the plane of the rings over the following nine months.



At alternating intervals of about $13\frac{1}{4}$ years and $15\frac{1}{4}$ years, terrestrial observers are positioned to view the rings in their orbital plane. The last occasion was in 1966; the next will be in 1995.

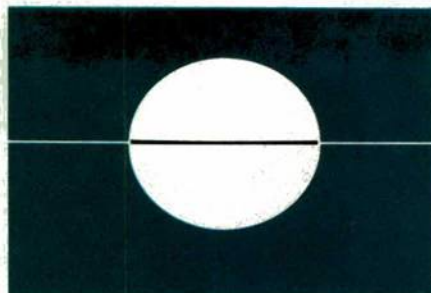
What's happening isn't too hard to understand: Saturn's equator (and ring plane) is tipped about 27° with respect to the planet's orbit around the Sun, just as the Earth's is tipped $23\frac{1}{2}^\circ$.



Since Saturn circles the Sun once every $29\frac{1}{2}$ years, twice each saturnian year we see the rings maximally open (once with the northern surface exposed, once with the southern); in between, we pass through the ring plane and see them edge-on.

The difference between the two ring plane crossing intervals comes from the eccentricity of Saturn's orbit. When near perihelion (closest approach to the Sun), the planet is moving faster than at aphelion, shortening the interval.

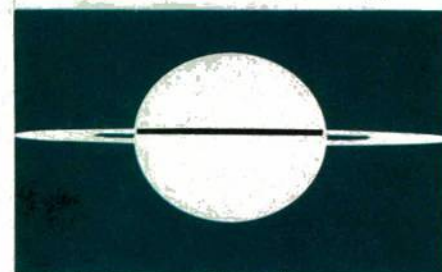
However, because the Earth's orbital plane and that of Saturn aren't coincident, there's more to a ring plane passage than just a quick trip once through. Until October 27th of this year, the rings will steadily close up. Since the Earth and Sun have both been on the same side of the rings (the southern side), the visible ring surface is sunlit.



From October 27, 1979 until March 3, 1980, the Earth will be on the north side of the rings, while the Sun will lie south of them. The rings will then be backlit. (We'll explain what this means to the observer in a minute.) From March 3 until March 13, 1980, both Earth and Sun will be on the rings' north side. Between March 13 and July 23, 1980, the Sun will be to the north of the rings, while Earth will view the southern side. Finally, after July 23rd, both Earth and Sun will be on the northern side of the rings, where they'll stay until the next ring passage in 1995.

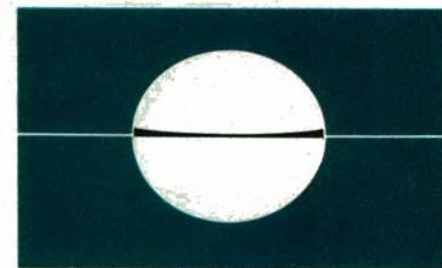
So much for theory; now what's it all mean for the telescope owner? As the rings close up, they'll become thinner and dimmer until at some point, perhaps only a day or so away from

edge-on, they'll disappear in all but the largest instruments. Naturally, the point of disappearance (and reappearance)



will be earlier (and later) in small telescopes than in bigger ones. When will the rings vanish in your scope? (To see how ring visibility is controlled by aperture, place a sheet of cardboard with cut-out circles of varying sizes over the end of the tube.)

When the rings are backlit, that is, when the Sun and Earth are on opposite sides of the ring plane, supposedly the rings are invisible. But during ring passages over the past century, observers with moderate to



large telescopes (12" or greater, say), have glimpsed the rings even when Sun and Earth lay on opposite sides of the rings.

In a small telescope, you can expect the rings to disappear totally during these periods, but if you have a medium or larger instrument, look carefully: you just might catch sight of the ghostly rings! ☛

— Robert Burnham



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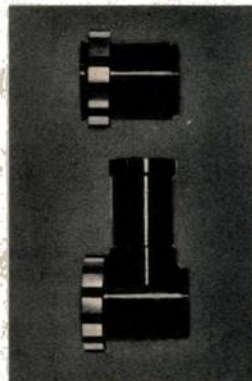
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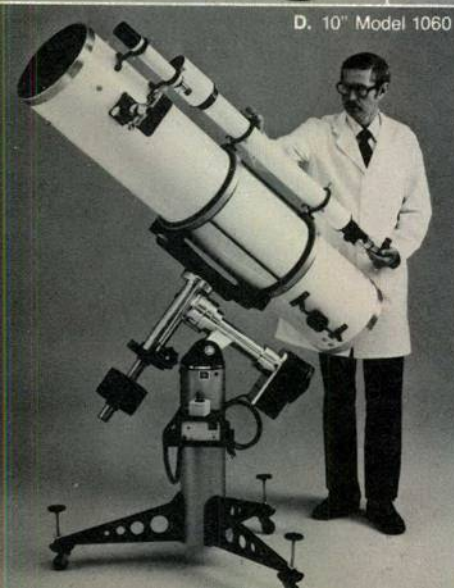
A. 6" Model 591



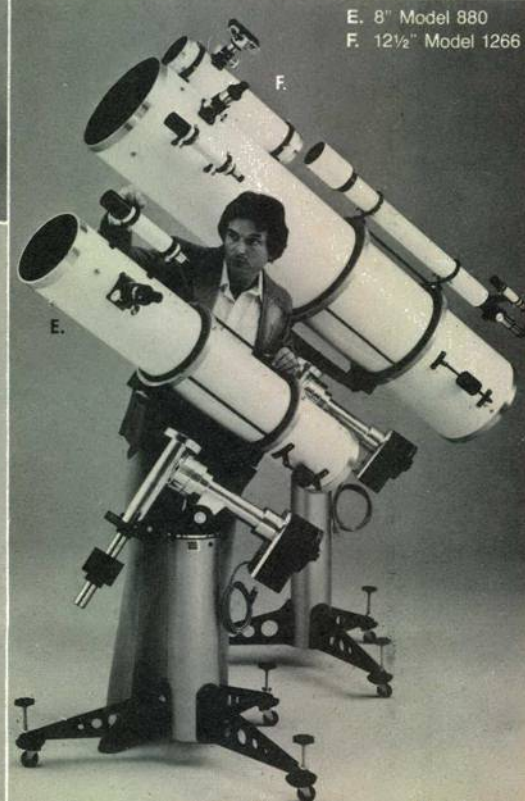
B.
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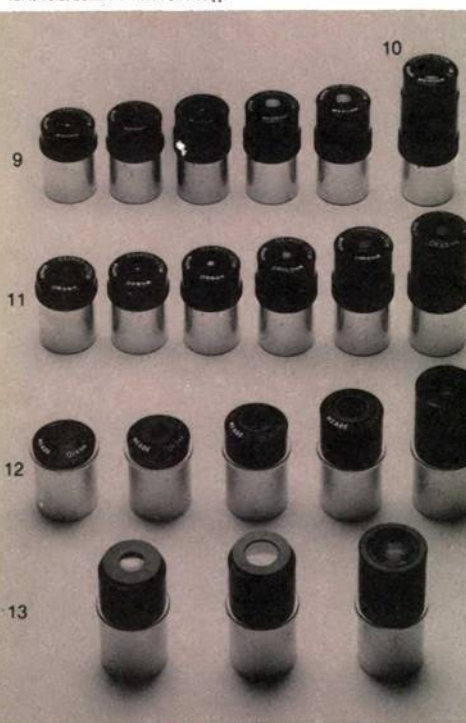
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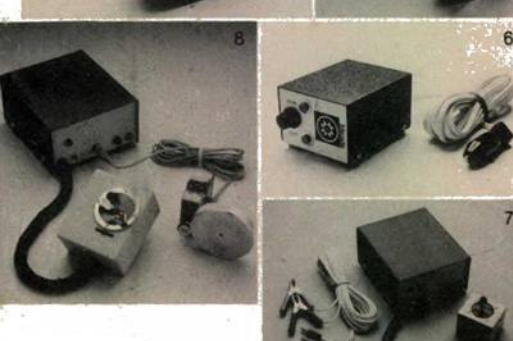
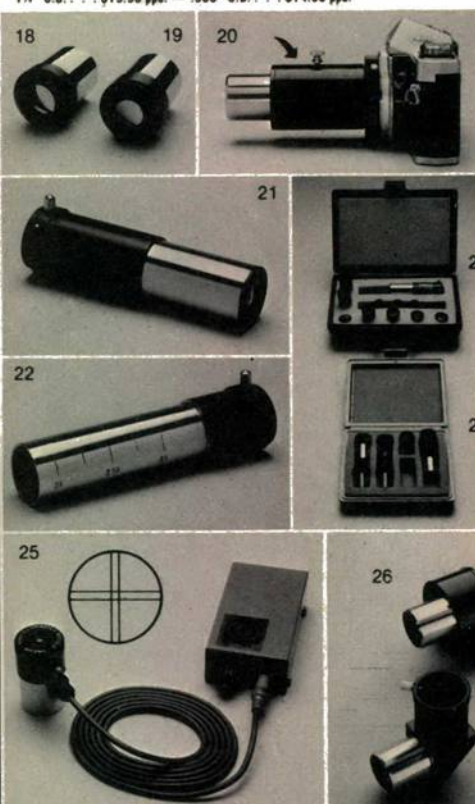
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Quality Remains the Most Important Factor

Certain highly regarded telescope manufacturers would have us believe they discovered large volume, low cost production techniques which facilitate rapid generation and fast polishing of large optical surfaces while maintaining high quality. It is certainly true that current commercial practices employed to make optics for popularly priced binoculars and camera lenses are adequate to secure reasonably good images from these relatively low power systems, in as much as the residual aberrations remain tolerable at the magnifications involved. These methods are just as applicable to large elements, but the important thing to remember is that low power systems meet their specifications without ever approaching the accuracy needed for imagery at the diffraction limit.

No matter what impression such implied claims may produce, high power instrument performance which is limited only by the wave nature of light has never been and never will be inexpensive; simply because high power telescope optics must meet far more stringent requirements. In any system intended to produce highly magnified images, the surfaces of its lenses or mirrors must follow computed design closely and possess smooth precision far greater than the optical wave fronts they are expected to handle. To achieve this, all components must be hand finished and rigorously tested even before they get assembled for trial as a complete telescope. No large volume production techniques exist that can yield anything beyond an approximation to the precision required for such ultimate applications.

All observers, including beginners, have the ability to evaluate the degree of finesse in the optics of any telescope. It takes no expertise or knowledge of theory, but requires just a little time, a first or second magnitude star high overhead, and a good eyepiece strong enough to provide at least 25 power per inch of aperture of the instrument. The things to hope for are perfect concentricity and roundness of the bull's eye pattern formed by defocusing the star slightly while it is in the center of the field. Lack of radial symmetry indicates misalignment or coma, and the slightest departure from absolute roundness shows that one or more optical surfaces are warped or astigmatic. These are the two most damaging of the basic optical errors, which of course, makes them the easiest to detect, provided the observer uses enough magnification and refrains from going too far out of focus. The effects of the other possible errors, such as spherical aberration and small period low amplitude ripples or zones prove more subtle and usually lead to a general wish for better seeing when scrutinizing planetary discs, no matter how steady the air may be at the time.



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The Top 21 Deep-Sky Objects

Let's say you have a friend visiting one evening, one who knows nothing about astronomy, and he asks you to show him some things through your telescope. As it turns out, the night is clear and beautiful, with no Moon (which would make things too easy!), and thus perfect for deep-sky objects. What are you going to show him?

All telescope owners have found themselves in this situation at some time or other. Fortunately, most of us have a number of favorite objects we can quickly zero in on, but all too often we discover that friends are singularly disappointed in seeing nothing more than a dim oblong blur where they expected, perhaps, to see psychedelic colors, strange swirling forms, weird alien worlds, and maybe even hurtling starships.

At this point, of course, you have to explain just what a telescope is actually capable of, and that the excitement lies in the knowledge of what it is you're seeing and the realization that you're actually viewing the object itself — not a photograph, or drawing, or painting, but the very light it emitted long ago.

Just what are the most interesting deep-sky objects to show your friends? The following pages include the most spectacular — 21 in all — not only good for celestial sightseeing but also each is representative of a larger class of objects.

They're well spread around the sky so at least a few will always be up. Of course, it isn't easy to narrow things down so far, and undoubtedly you'll find several of your old favorites omitted.

The Pleiades

The Pleiades have to be on almost any list. Your striking first glimpse of so many stars visible with a low-power telescope where only six (or, rarely, seven) are seen with the naked eye, can't fail to delight. And there's an opportunity here to mention the Pleiades are a typical open cluster — a group of young, hot stars born relatively recently and bound together by mutual gravitation in a celestial fraternity.

The Double Cluster

Visible to the naked eye, the Double Cluster is one of the most spectacular telescopic sights in the heavens — use a small telescope at low power and both clusters will be seen in the same field of view. Over 7000 light-years separate us from the Double Cluster.

M-37

This bright and striking cluster is one of the most beautiful in a small telescope. Over 4000 light-years distant, it's one of three especially pleasing open clusters in Auriga (M-36 and M-38 are the others), and it has a distinctly ruddy star in the center of it.

The Great Cluster in Hercules

M-13 represents a very different kind of cluster (globular rather than open), but the difference is much more than one of appearance. The globulars are huge associations of a hundred thousand or more old stars, far more distant — 25,000 light-years in the case of M-13 — from us than the younger open clusters. A 4 to 6-inch telescope will show some of the individual stars in M-13 sparkling against the fuzzy glow of tens of thousands more stars still unresolved.

There are two even more impressive globular clusters in the sky, but both (Omega [ω] Centauri and 47 Tucanae) lie too far south to be seen easily from northern latitudes.

The Great Nebula in Orion

There can be no argument; M-42, naked eye visible in the "sword" of Orion, explodes with beauty even at low magnification with a small telescope. Here you're looking at an actual birthplace of stars; this vast cloud of glowing hydrogen is manufacturing stars on an (astronomically) short time scale. Don't forget to note the Trapezium at its center, the tiny group of four stars which is among the very youngest you can see in the sky. (Use high magnifications on the Trapezium.)

The Omega Nebula

Also called the Horseshoe or Checkmark Nebula because of its

The Great Nebula in Orion

The Pleiades

Dumbbell Nebula

The Ring

shape, this large diffuse nebula lies about 3000 light-years from us. Most people see a shape like that of the number "2" with the straight bar particularly bright and long. As you look at this vast cloud of glowing gas through a small telescope, remember that its dimmer parts extend much farther out than can be seen visually.

The Lagoon Nebula

The complex and detailed structure of this large diffuse nebula can be studied with even small telescopes. Everyone should be able to see the large dark lane of obscuring dust extending across the glowing cloud. The sixth magnitude star 9 Sagittarii, an extremely hot star embedded deep within the nebulosity, is responsible for this celestial display. The open cluster of stars buried in the nebulosity (NGC-6530) contributes to the richness

of the field of view. Use as low a power as you can to catch as much as possible of this nebula.

The Ring Nebula

The planetaries are yet another kind of nebula. They consist of expanding shells of gas cast off by aging stars during a period of instability. The Ring Nebula, like most of this type, should be viewed at a high magnification because of its small size (83" x 59"). Beginners may have difficulty seeing M-57 as a ring rather than just a tiny oval patch in a small telescope, especially if seeing is not good. The central star which gave birth to the nebula is too dim (about 14th magnitude) to be seen in a 4 or 6-inch telescope.

The Dumbbell Nebula

This second planetary nebula on our list is a classic. The "dumbbell" shape

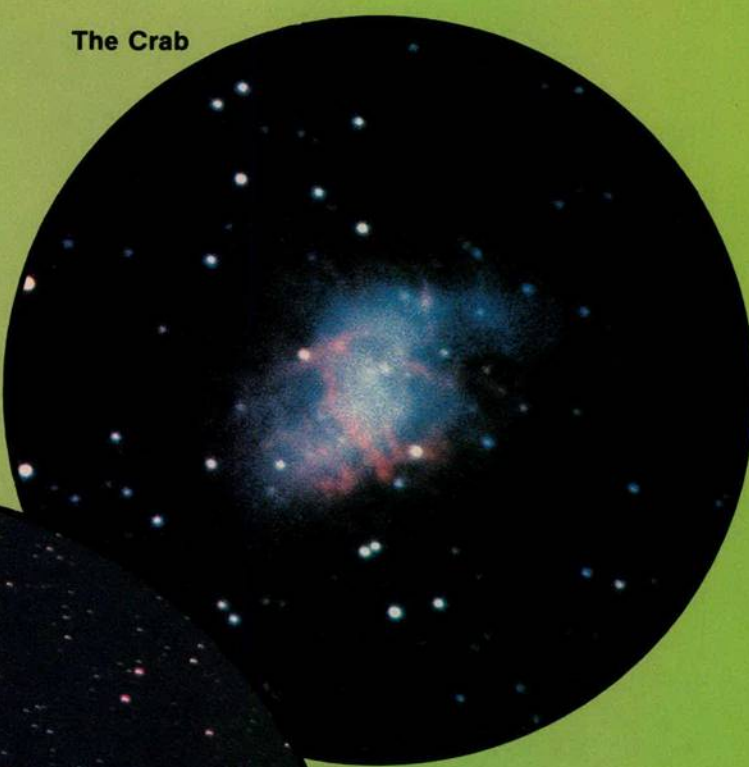
should be clearly seen even at low power, and you may even detect the faint greenish tint. The central star responsible for this celestial "neon" display is too faint for a 4 to 6-inch telescope. Point out to your friends that the dumbbell they see is, in reality, 3 light-years long and shines by the excitation of the gas by invisible ultraviolet radiation from the central star.

NGC-3132: the Eight-Burst Nebula

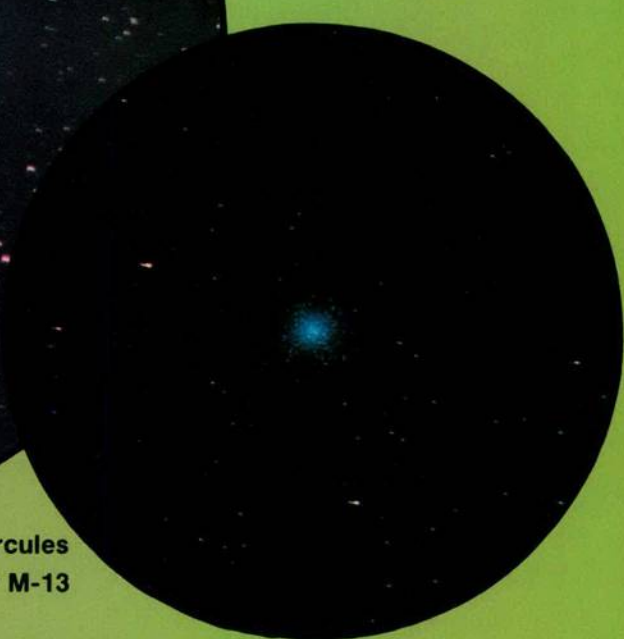
This planetary is undoubtedly one of the most impressive in the sky, but because of its extreme southern declination (-40°) you may not be able to see it well. Try for it anyway —



The Double Cluster



The Crab



The Great
Galaxy in Andromeda



The Hercules
Cluster M-13

located in Antlia, NGC-3132 surpasses the Ring Nebula in detail and brightness. The tenth magnitude central star should be visible in a small telescope.

The Crab Nebula

Although often classed with the planetaries, the Crab is actually a very different kind of object. Chinese astronomers saw a brilliant "guest star" here in 1054 A.D. Now we see the exploding material of a supernova: a vast, rapidly expanding cloud of gas cast off by a massive stellar cataclysm over 900 years earlier. Moderately high magnifications are best for the Crab Nebula, which looks rather more

like a baked turkey than a crab in a small telescope.

The Great Galaxy in Andromeda

No list of deep-sky showpieces is complete without M-31, the greatest of our neighbor galaxies. Under good skies it's easily visible to the naked eye. Your 4 to 6-inch telescope will reveal it as an oval glow, noticeably brighter towards the center. You actually see only the bright central hub of the vast pinwheel and the inner spiral arms, since the outer spiral arms are quite dim. The light you see has traveled

Facing page: Top left, the Great Nebula in Orion (M-42) by Phil Poirier. Bottom left, the Dumbbell Nebula (M-27) by Robert Provin. Center, the Pleiades (M-45) by Steven Wissler. Bottom right, the Ring Nebula (M-57) by Leo Henzl. This page: Top left, the Double Cluster (h and Chi Persei) by David Healy. Center, the Great Galaxy in Andromeda (M-31) by P. Maley. Top right, the Crab Nebula (M-1) by Ben Mayer. Bottom right, the Great Cluster in Hercules (M-13) by Bob Kimmel.

THE TOP 21

Name	Common Name	R.A. (1950)	Dec.	Type	Constellation
M-31	Great Galaxy	00 ^h 40 ^m	+41.0°	galaxy	Andromeda
Omicron (o) Ceti	Mira	02 ^h 17 ^m	-3.2°	variable star	Cetus
h & Chi (χ) Persei	Double Cluster	02 ^h 17 ^m	+56.9°	open clusters	Perseus
Beta (β) Persei	Algol	03 ^h 05 ^m	+40.8°	variable star	Perseus
M-45	Pleiades	03 ^h 44 ^m	+24.0°	open cluster	Taurus
M-1	Crab Nebula	05 ^h 32 ^m	+22.0°	planetary	Taurus
M-42	Orion Nebula	05 ^h 33 ^m	-5.4°	diffuse nebula	Orion
M-37		05 ^h 49 ^m	+32.6°	open cluster	Auriga
Beta (β) Monocerotis		06 ^h 26 ^m	-7.0°	triple star	Monoceros
M-81 & M-82		09 ^h 52 ^m	+69.6°	galaxies	Ursa Major
NGC-3132	Eight-Burst	10 ^h 05 ^m	-40.2°	planetary	Antlia
Zeta (ζ) Ursae Majoris	Mizar & Alcor	13 ^h 22 ^m	+55.2°	double star	Ursa Major
M-51	Whirlpool Nebula	13 ^h 28 ^m	+47.5°	galaxy	Canes Venatici
M-13		16 ^h 40 ^m	+36.6°	globular	Hercules
M-8	Lagoon Nebula	10 ^h 02 ^m	-24.3°	diffuse nebula	Sagittarius
M-17	Omega Nebula	18 ^h 18 ^m	-16.2°	diffuse nebula	Sagittarius
Epsilon (ε) Lyrae	Double-Double	18 ^h 43 ^m	+39.6°	multiple star	Lyra
M-57	Ring Nebula	18 ^h 52 ^m	+33.0°	planetary	Lyra
Beta (β) Cygni	Albireo	19 ^h 29 ^m	+27.9°	double star	Cygnus
M-27	Dumbbell Nebula	19 ^h 57 ^m	+22.6°	planetary	Vulpecula
Delta (δ) Cephei		22 ^h 27 ^m	+58.2°	double/variable	Cepheus

over 2 million years before entering your eye!

The Whirlpool Galaxy

The second galaxy in our list will not look like a whirlpool in your telescope, but you should be able to see both the galaxy itself and the fainter glow of its companion (NGC-5195) just to the north. The most distant object on our list, M-51 is about 15 million light-years away — you're seeing light 15 million years old.

M-81/M-82

Use a low power eyepiece on this field and you'll be able to show off two beautiful galaxies at the same time. At a distance of over 7 million light-years, M-81 and M-82 appear as oval ghostly glows, M-82 the more elongated and spindly. Compare the appearance of these two galaxies: M-81 is a typical medium spiral while M-82 is a peculiar irregular galaxy.

Mizar and Alcor

Mizar and Alcor are the prime example of a multiple star system. With the naked eye, you can point out two stars just separable. When you exhibit them through your telescope, your friends will soon discover the system is more complex. Mizar itself is a double star, with two white components separated by a mere 15 seconds of angle, while Alcor shines 12 minutes — about 1/3 the Moon's diameter — away. (The star you see between Alcor and the double Mizar isn't part of the system.) Furthermore, each of the three stars of the system is

itself a double star, making this a six-star multiple system in all.

Albireo

Orange and blue, the two bright components of Albireo are easily seen at their wide separation. Even good sporting or birding binoculars can "split" this pair. The vivid color contrast of this magnificent double will be even more dramatic in a small telescope than in a large one.

The Double-Double Star:

Epsilon (ε) Lyrae

A strikingly beautiful quadruple system, Epsilon (ε) Lyrae consists of two very close double systems separated by 208 seconds of arc. Moderate to high power is necessary to see each of the two main components themselves as double, since their separations are just under 3 seconds of arc. All four stars are early A-type suns and look white in color to most observers. (For a typical eyepiece view, see the drawing on p. 85 of *ASTRONOMY*, July 1979.)

Beta (β) Monocerotis

The finest triple star in the sky, Beta (β) Monocerotis appears as three yellow-white stars of nearly equal brightness arranged in a triangle 10 seconds of arc across. Think what an interesting sky you'd find on a planet orbiting one of these three suns.

Omicron (o) Ceti:

Mira the Wonderful

Of the three variable stars on our list, each is a different type. The first is Mira (Omicron [o] Ceti), a long-period

variable. A red giant star, it fades from second magnitude down far below naked-eye visibility to tenth magnitude and then brightens again to second magnitude over a period of 332 days. The ever-varying brightness of Mira reminds you that stars are not static entities: some pulsate (like Mira), some explode, and still others evolve placidly. For stars, as for people, change is constant.

Beta (β) Persei: Algol

Rightly the most famous of the eclipsing variables, Algol, the "Demon Star" (Beta [β] Persei), winks at us once every 68 hours 48 minutes 56 seconds. Dropping more than a magnitude in brightness over a five hour period, an eclipse of Algol can be followed even with the naked eye. The two stars comprising the system are estimated to be about 6½ million miles apart, or much closer together than the Earth is to the Sun. The eclipse happens when the brighter star is partially covered up by its fainter companion. Algol is relatively nearby: only about a hundred light-years from our solar system.

Delta (δ) Cephei

Delta (δ) Cephei is included on our list as representative of the class of Cepheid variable stars which have been so important in the history of astronomy. These stars enabled astronomers to make the first estimates of the distance to neighboring galaxies. (Delta Cephei is discussed in detail in this month's *Star Dome*.)



Some things in life provide a special joy and pride, like a well-precisioned chronometer or finely tuned sports car. Both have something in common—the special blend of technology, fine craftsmanship and functional design.

The Pentax 100 telescope is of this rare breed. It is possibly the most technologically advanced instrument you will ever experience.

The Pentax 100 has optics fully coated on all surfaces (not just the fourth surface) and is available with a three element apochromat for the absolute perfectionist. Its quartz crystal oscillator keeps perfect tracking frequency and the drive gears are fully enclosed so as to not catch dirt and grime. But most of all note the tip of the polar axis housing—the indexed eyepiece will give you exact and instant polar-axis adjustment.

Many other features of this telescope make it the one and only choice for you. Put your hands on the controls of a Pentax 100. Then, and only then, can you appreciate the best.

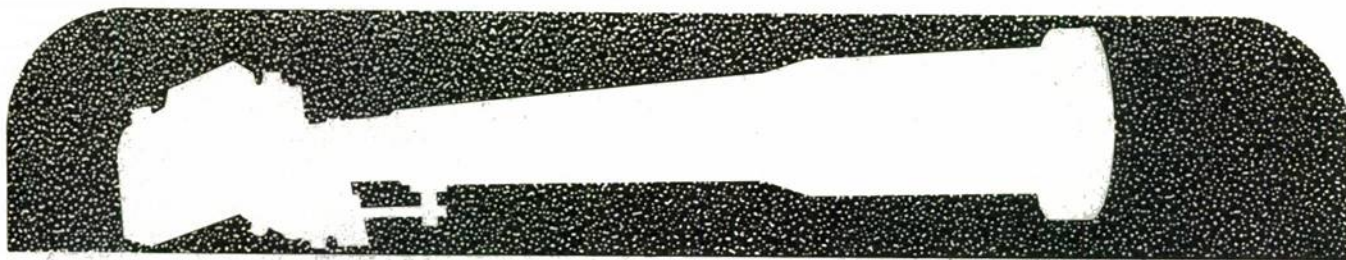
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PHOTOGRAPHY IN ASTRONOMY

How to Get Steady Pictures

Getting steady pictures is probably the one biggest headache would-be astrophotographers face. Many beginners, discouraged by shaky and blurred first attempts, give up altogether and resign themselves to admiring other people's shots — at least until they can afford that superduper telescope with a rock-

steady mount that only costs a kilobuck and a half....

But giving up is no way to solve a problem, and besides there's no guarantee that even expensive equipment will perform perfectly. The best way out of the dilemma is to learn how to use your present equipment to its fullest.

The Blurred Photo Problem

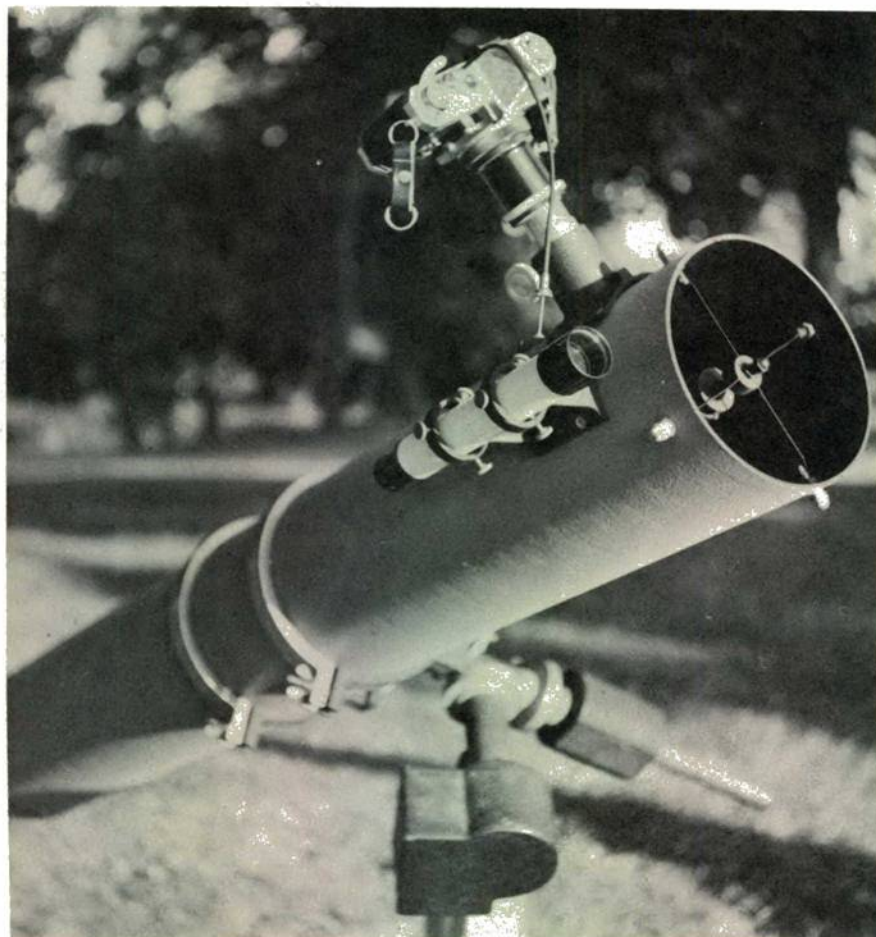
Even granting that Murphy's Law requires that every astrophotographer kick the scope during the exposure, you'll find that most of the blame for blurred photos can be traced to two causes: a wobbly telescope mount and/or camera shutter and mirror "slap."

Sad to say, the mounting on many commercial and homemade telescopes is undersized, often by a good deal. (Put a 4 1/4" scope on a 6" scope's mount sometime if you want to check this; the improvement in performance will be substantial.) If your scope is homemade, then beef up that mounting. But supposing you've purchased your telescope ready-made, and anyway aren't too handy with tools, what then?

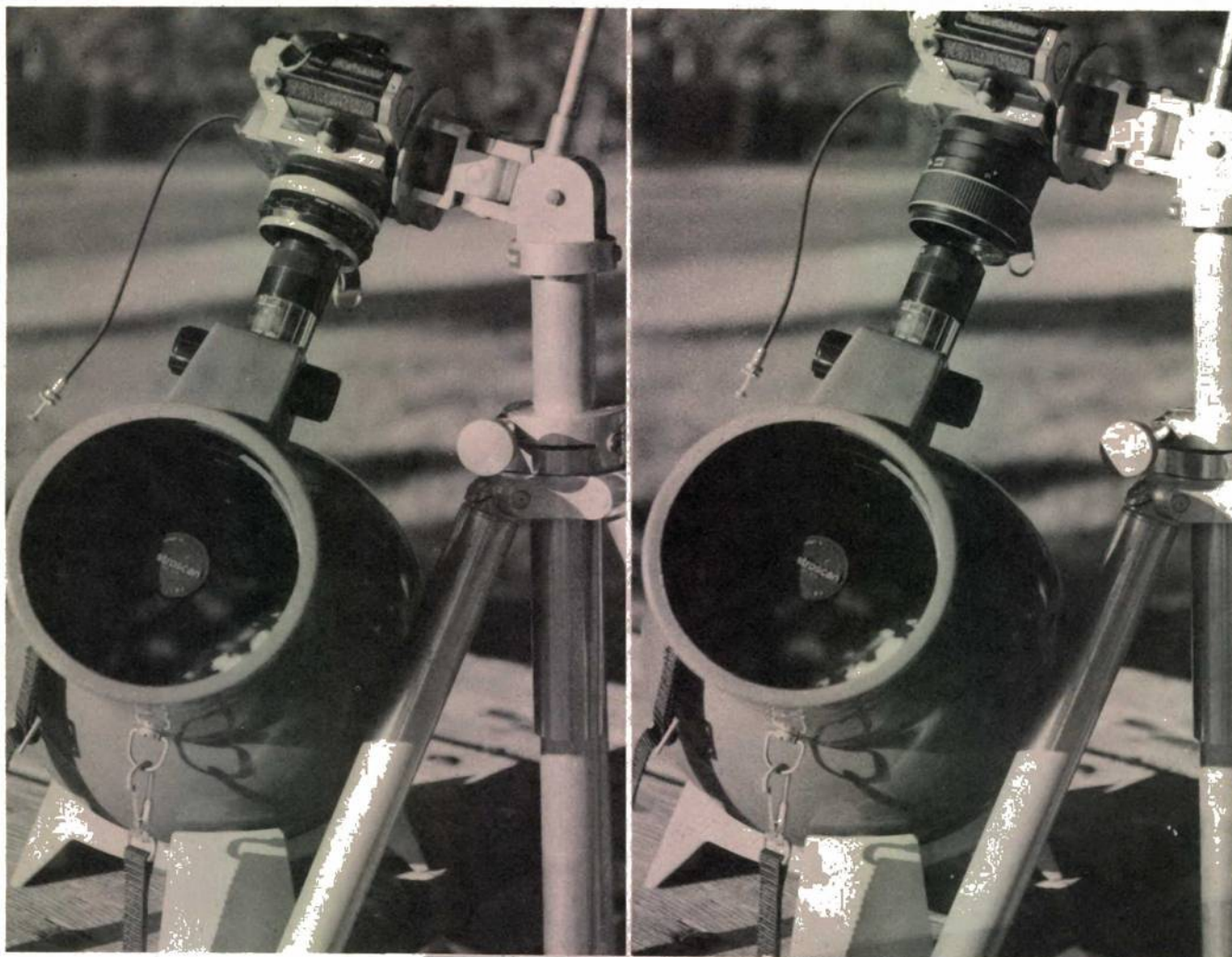
Shake, Rattle & Roll

First of all, go over the mounting carefully. Dig out the instruction manual and locate all parts which move. Look for any looseness that can be eliminated. Poor fit in machined shafts can't be corrected, but loose screws can. When you tighten them, be careful to use a screwdriver that's the proper size; don't use one which fits too loosely into the head of the screw, or you'll just mash the metal. The same goes for tightening: never crunch a screw or bolt down as hard as you can; you'll end up stripping the threads or shearing off the head. But leave nothing loose.

Once all the adjustments seem to be tight, take a look at the clock drive. This will probably mean removing its



The classic astrophotography set up, using either prime focus or eyepiece projection, is shown here. The camera is attached by an adapter directly to the eyepiece focuser. The telescope is a 6" 1/8 reflector.



Above and right: The afocal system conveniently separates camera and telescope, and allows the use of different focal length lenses for varying powers of magnification. Use a cable release for exposures 1/30 second or faster.

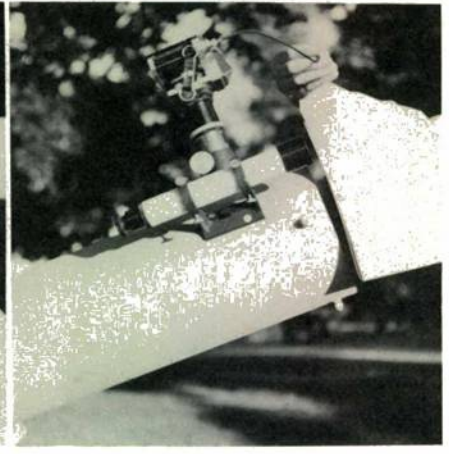
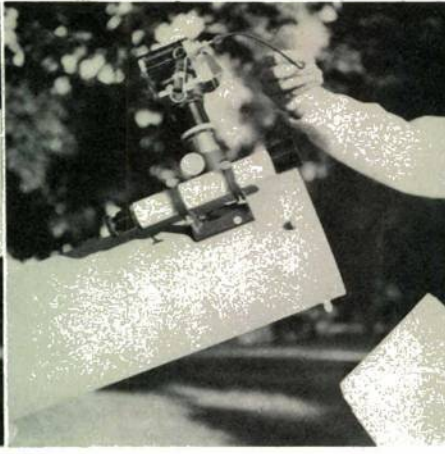
protective housing; do so carefully. Check if the gears have any slop or "backlash" in their fit. The manual should tell you how to adjust the fit on your particular drive mechanism. Check the tension on the clutch plate. It should slip moderately easily for visual viewing, and be perhaps a bit tighter for astrophotography.

The gears themselves may be worn. If your scope is new this won't likely be the case, but if the teeth of the gears are worn out, then so is your drive. You can get the gears replaced, but a new mechanism would cost approximately the same and in most cases would perform better.

Optical Integrity

With reflectors, it's a good idea to check that the primary mirror and diagonal are solidly mounted. The diagonal should have almost no play at all — but consult your telescope's manual before adjusting anything. The primary mirror is a little trickier





The "hat trick" brought up-to-date: a quick flick of the wrist will produce vibrationless exposures from a fifth of a second to as long as you like. Be sure not to touch the telescope tube, though!

— it can't be clamped because the forces used to hold it would ruin its fine optical figure. But it shouldn't be free to flop around either. For deep-sky astrophotography, a few well-placed dabs of RTV rubber (bathtub caulk) will fill the gaps without transmitting strain to the mirror.

Cheaper and poorly-made telescopes sometimes have loose or inadequate

focusing arrangements. If the focuser can't hold the camera without shaking, replace it with a better focuser.

After giving the telescope and mounting a thorough once-over, make certain that the tube is well-balanced when you place it in the saddle. Loosen the declination and right ascension clamps to let the scope swing freely. Left to itself, does the tube move? Adjust the counterweight and telescope, first in declination then in right ascension, so that the scope stays at whatever attitude and angle you place it.

Now for the moment of truth: here

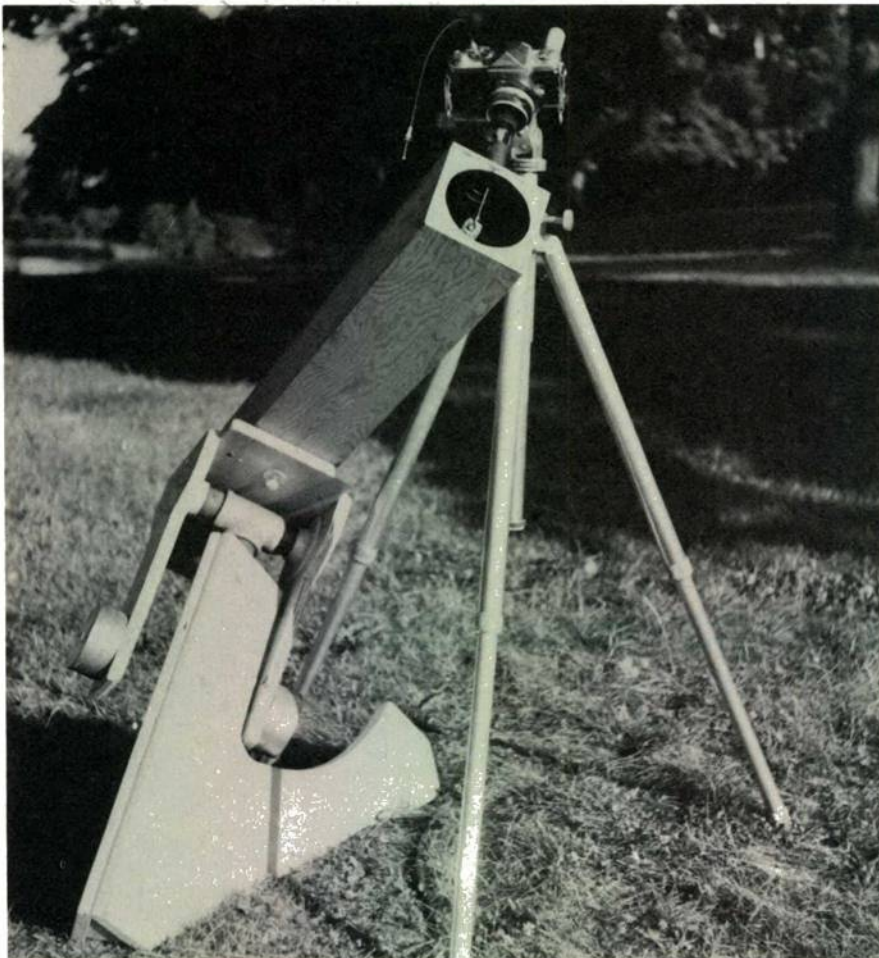
you find out what your scope is really good for. If it now moves smoothly, resists being shaken, and holds its position wherever set, you're on the road to astrophotography. If it still has backlash, slop, and won't sit tight when you want it to, then let's face it, you're not going to do half-hour exposures on the Veil Nebula. But don't give up, all is not lost: you'll probably still be able to get fine shots of the brighter objects in the sky.

Add a Beanbag...

One of the least likely-looking of all observing accessories is a cloth bag about a foot long by three or four inches wide, three-fourths filled with sand or fine gravel. In fact, you could probably use as many as a half dozen of them. What for? They're weights to help dampen out vibration in a wobbly mount. You can also use them to balance out the weight of the camera by draping them over the declination axis.

Before we go on, you ought to make sure you haven't stacked the deck against you by ignoring a couple of "environmental" factors. When you set up your mounting and telescope, put them on firm ground that's level. If it isn't level (or at least within the adjustment capabilities of your mounting), move to a spot that is. Roadside sites, though convenient, are not all that good from a stability point of view. Passing cars will often shake the ground and your telescope. If you have a favorite site in the country, try to make arrangements with the owner of the adjacent land so you can get away from the road.

Another factor to pay heed to is wind. Even the best mountings will wiggle in a 25 to 30 knot breeze. Pick nights when the wind is light or nonexistent, or find some way to shelter your scope. Windless nights



The overall view of an afocal arrangement shows one way to place the tripod so as to get the camera lens looking into the eyepiece of the telescope, in this case a 4 1/4" f/10 reflector.

No matter what type of telescope you own, you can usually adapt it to do shoot-into-the-eyepiece astrophotography. For best results, use a sturdy tripod.

often have superb seeing so take advantage of them.

Mirror Slap & Shutter Shake

All single-lens reflex cameras suffer from a congenital defect that's hard to get around: when you press the shutter, the mirror is flipped up and out of the light path. This imparts a vibration to the camera, and when your camera is perched on the end of a great long tube which is moving at the moment of exposure...well, you're going to get blurry photos. Moreover, you'll get another vibration from the focal-plane shutter as it snaps open in front of the film.

Mirror slap can be avoided by locking the mirror up after you focus. Many 35 mm SLRs have this feature, so check in your owner's manual to see how yours works.

The Old Hat Trick

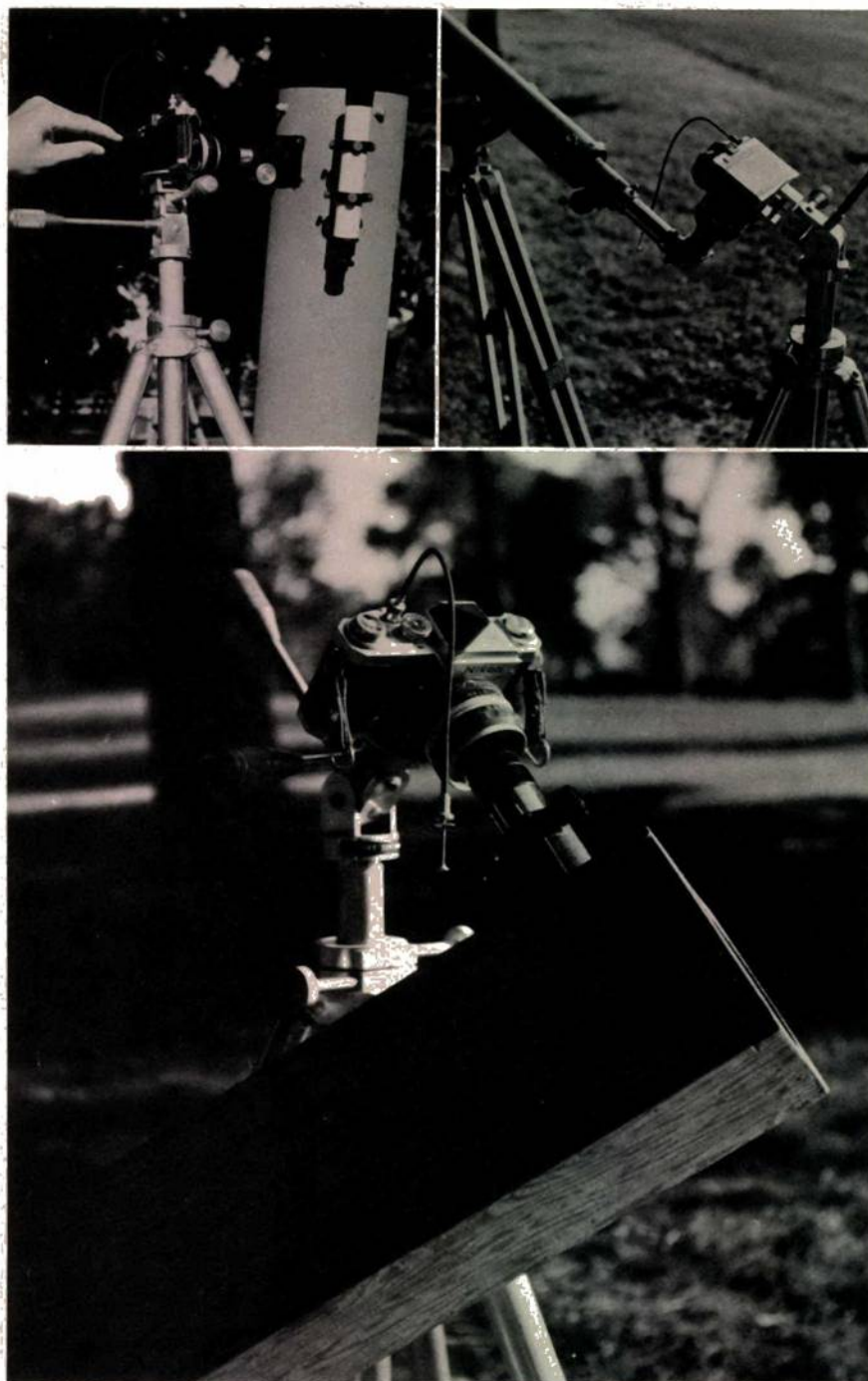
The shutter shake can't be avoided as easily, but there is another method which takes care of both mirror and shutter vibration at the same time and doesn't need any fiddling. It's called the "hat trick" (though seldom done any more with a real hat). Set up your shot, get it focused, and then, holding a black sheet of cardboard in front of the telescope (*but not touching the tube!*), trip off the shutter using the B or T setting. Give the vibrations about 5 to 10 seconds to settle down and remove the cardboard to start the actual exposure. When the exposure time's up, cover the aperture with the cardboard and close off the shutter. Properly done, this'll net you clean, unjarred shots. With practice you can even work it (with a quick flip of the wrist) on exposures as short as a fifth of a second.

It may be mentioning the obvious, but make sure you have a cable-release device and use it for all exposures 1/30 second and longer. If you think you get bad vibrations from setting off the shutter, observe sometime what happens when you put your ham-fingers onto the camera to trip the shutter!

Can Hassles Be Avoided Entirely?

For the brighter celestial objects, there's a way to simplify mounting a camera stably on a telescope: separate them, putting the camera on a tripod. This neatly divides things so that no camera vibration gets transmitted to the scope.

The technique works best with the afocal optical arrangement (see "Astrophotography With a Small Telescope," *ASTRONOMY*, October 1978). In this system, your camera is used complete with lens. Set the scope on the object and focus the eyepiece by



looking through it as you normally would. Then set your camera-lens focus to infinity. Having put the camera on its tripod, aim the lens straight into the eyepiece. Everything will then be in proper focus and you can start shooting away without fear of shaking the telescope. You'll get your best results on objects bright enough to keep the exposure down to a few seconds.

If your camera tripod is like many on the market, it may be a little wobbly. Hang your sandbags or any other weight on the tripod between the legs. This will add stability — but use a cable release anyway, and avoid touching the camera whenever possible.

Get Started Now

Getting good, sharp, unblurred astrophotos is unquestionably a challenge, but despite what's often thought by beginners, no great load of advanced, expensive equipment is necessary to meet it. Why wait around for that Great Telescope that'll solve your every problem and which always lies just over the (financial) hill? Start in now with what you have; all you need are care and determination, two qualities most everyone can summon up. These, coupled with practice, will provide so many tangible rewards of celestial wonders you may end up never wanting that Great Telescope after all. ☛

— Robert Burnham



ASTRONOMY REVIEWS

The Solar System

by John A. Wood

196 pages, hardcover, \$10.95*
Prentice-Hall, Inc. (1979)

In a previous book, *Meteorites and the Origin of Planets* (McGraw-Hill, 1968), John Wood presented a concise and readable survey of meteoritics which has dated amazingly little in the past 11 years. In his new book, Wood attempts to survey the fundamental properties of the system formed by the Sun, planets, satellites, and minor bodies. He presents the astrophysical background that sets the stage on which the solar system formed, and finally discusses our current understanding of the system's origin.

In his introduction, Wood surveys the course to be followed, and makes some very pertinent comments on the uses and limitations of scientific models. A brief outline of the essentials of celestial mechanics follows, covering orbital motion, orbit changes of comets and asteroids, and the tidal evolution of moons, Mercury, and Venus. An error occurs where the spin-orbit coupling of Venus and Earth is discussed. The rotation of Venus is not quite exactly synchronized to face Earth at inferior conjunction. The reason for the near coincidence remains unexplained.

The surfaces of the terrestrial planets, and the internal and external processes that shape them are discussed next. Global geologic maps of Mercury, Earth, the Moon, and Mars are used to compare and contrast the surface histories of these four planets. On the Mars map, there's an error in the age sequence chart which implies that collapsed terrain, channel materials, and the volcanos are the oldest surface features. In fact, except for the relatively young polar ice and dust deposits, these features are among the youngest on Mars.

The section on planetary interiors is excellent. The limited data available are described, followed by a discussion of how scientists make models of the structure and thermal evolution of planetary bodies. Planetary atmospheres are discussed less expertly, although their physics and major properties are well covered. In the

section on escape of atmospheres, a temperature of 1000° Kelvin is used in the discussion of hydrogen and helium escape from Venus. The temperature of Venus' exosphere was measured by ultraviolet instruments on Mariners 5 and 10 and was found to be around 250° K. This implies a very slow loss-rate for these gases. The model of water loss from Venus, which Wood supports, appears unlikely and it is probable that Venus accreted with little water to begin with.

Coverage of the outer planets and their satellites is very brief, but the important points are well dealt with. The diagram of the positions and sizes of the satellites is excellent. Chapter 5: "Rocks from Space" is Wood's specialty. His discussion of the nature, basic chemistry, and history of meteorites and lunar samples is succinct and expert.

Passing beyond the solar system, chapter 6 outlines the Sun, stellar evolution, and the synthesis of the elements. This sets the stage for the last chapter: "Origin of the Planets." First, the basic physical and chemical processes operating in the pre-solar nebula are outlined. Because there are several competing theories of the accretion of terrestrial planets, the author chooses to discuss each briefly, pointing out their major strengths and weaknesses. Wood then presents a compromise model, using the best supported features of each, as a working guess of how the terrestrial planets formed. The text ends with these planets' earliest evolution, origin of the gas giants and their satellites, and the possibility of other solar systems. The book itself concludes with a brief glossary of mineral names (definitions of rock types should have been included), and a well-selected reading list.

In a space of 185 pages of text, and with a photo-graph, or table on most of them, only the broadest coverage of the subject is possible. It is a tribute to John Wood's long experience in the field, and to his careful and reasoned judgement, that the book succeeds in covering the subject thoroughly, with a minimum of gaps. The book is written at approximately a freshman

college level, and the author does not avoid presenting equations where he feels they are important. However, with one exception, they are all simple algebra and trig equations, and have sufficient explanation to aid the non-mathematical reader.

If this book dates as slowly as his earlier book, it will be a useful, handy reference and survey of the solar system for a decade to come. *Edwin Strickland.*

**Also available in paperback for \$6.95.*

Murmurs of Earth, The Voyager Interstellar Record

by Carl Sagan *et al*

273 pages (illus.), hardcover, \$15.00
Random House (1978)

What can you say about a young civilization inhabiting the third planet of an ordinary G2 star found out in the sparse suburbs of the galaxy? What pictures would you show to wholly alien eyes, and what music would you play for alien ears? How would you go about packaging all this information so that it will last for millions of years?

These were the tasks facing a small group of persons with limited time and an even more limited budget when the opportunity arose to include something more than a plaque aboard the two Voyager spacecraft, bound for interstellar space via the outer planets. *Murmurs of Earth* is a beautiful and fascinating account both of the process of decision and of what was finally decided upon for inclusion in the Voyager interstellar records.

Following an introductory essay by Carl Sagan and an account of the background of the project by F.D. Drake, successive chapters (each written by a different member of the team) deal with the visual images, the verbal greetings, the sounds of Earth life, and the musical selections included in the message to any extraterrestrial intelligences who may chance to find this interstellar time capsule. Appropriately enough, most of this book is composed of the actual contents of the Voyager record, with commentary on each selection. Every picture is reproduced (mostly in black

and white), for example, and each is described in detail. A final discussion of the planned Voyager mission to the outer planets along with speculation on the ultimate fate of these two galactic wanderers round out the story of man's first serious attempt to summarize the essence of life on Earth for alien minds.

The details of this story are particularly fascinating — and often amusing. It proved impossible, for example, to have the recorded greetings in various languages spoken by United Nations delegates for a number of bureaucratic reasons, such as the necessity of a committee vote on the question of whether or not to say "Hello" to the stars. Since this particular committee would not meet in time for a vote, Sagan was asked, in all seriousness, by a U.N. official if the Voyager launch couldn't simply be postponed for a while!

It is also interesting to speculate that because of the prudery of a public agency, an extraterrestrial culture may conclude that human beings have no sexual organs: a beautiful and sensitive photograph of a nude man and woman, far less offensive than many TV commercials, was vetoed by NASA. But then on the other hand, the aliens may be bright enough to perceive, correctly, that we humans are ashamed of our sexuality.

There is much to ponder in this whole affair. Our message to the galaxy is as much a social and political commentary on ourselves as it is an accurate summary of what we are all about. How, for instance, did all the members of the United States' House and Senate committees which deal with space science get their names included in the message? A moment's reflection on the dependence of NASA on the vagaries of the American political process provides the answer. But one wonders, if the record should actually be found, how many volumes of learned treatises will an alien civilization churn out in the vain attempt to decipher the meaning of these cryptic tables? And, even if they manage somehow to translate them, what will those alien beings make of the verbal greetings in 60 languages, including this one in the Chinese Amoy dialect: "Friends of space, how are you all? Have you eaten yet? Come visit us if you have time." To eat us?

The fact of the matter is that this is more a message to ourselves than a message to others, and there lies its greatest interest. As the members of the team well knew, the actual chances that either Voyager will ever be found by extraterrestrial beings is infinitesimal. As a commentary on how we see

ourselves in this age, the Voyager record challenges our values. Half the musical selections, for example, come from non-Western cultures. If this is surprising, it is because, as the text points out, "The Western world finds it convenient, in this season of its predominance, to imagine that because our voices speak most loudly, nobody else has much to say."

Presently it looks like Voyager 1 is ultimately bound for the constellation Ophiuchus, and Voyager 2 for Capricornus. There is an obscure red dwarf known as AC+79 3888, now in Ursa Minor, which the Voyagers could reach in only 60,000 years with one final course correction. Perhaps the record will be played sooner than anyone thinks.

Here on Earth a phonograph record of the aural parts of the message may never be released — the Byzantine complexities of copyrights and permissions are apparently more difficult to navigate than the solar system. It is one thing to get permission to send a musical selection or a sound into interstellar space, but quite a different task to include it on a record for Earthly ears. There is an ironic parable here, where once again the story of the Voyager interstellar record reveals more about us than we intended: it seems it is a great deal easier for us humans to say "hello" to the stars than to each other.

Deevey Schwartzburg

NEW BOOKS

The Crab Nebula

by Simon Mitton

194 pages, hardcover, \$14.95
Scribner's (1979)

Although the connection between the supernova of July 1054 (as recorded in Chinese annals) and the fuzzy smear of light in Taurus known as the Crab Nebula was made in 1921, curiously it took astronomers until the 1950s to begin exploiting the unique opportunity presented by the nebula. Since then, however, their interest has increased intensely. Because it is the only supernova remnant that can be seen both in detail and at a fairly early stage of its development, it has served as a "proving ground" for many astrophysical theories. The author, at Cambridge University's Institute of Astronomy, has put together a short but remarkably detailed and interesting account of what's known about "the Crab." The level of presentation has been kept entirely nonmathematical, and the book features some fine diagrams and photographs.

The View from the Earth 1979

by Guy Ottewell

33 pages, paperback, \$4.00
Dept. of Physics, Furman University,
Greenville, SC 29613 (1979)

Subtitled "a simple guide to the night sky and the events that will happen there," this book is a version of the author's **Astronomical Calendar** (sold by ASTRONOMY) intended for the beginner. He provides several pages of general explanation about the sky and then gives 12 two-page spreads, one to each month. The left page has a star map with constellations, planets, and the brighter stars. The other page gives details on what each month's celestial events will be.

Space Transportation Systems 1980-2000

edited by Robert Salkeld *et al.*

91 pages, hardcover, \$12.50
American Institute of Aeronautics and Astronautics
(1979) [address: 1290 Avenue of the Americas,
New York, NY 10019]

This is the first of a series by the AIAA's Technical Committee on Space Systems and basically is an assessment of what the Shuttle and its eventual followers will be useful for, as well as a forecast of demands made on any space transport vehicle. A person totally unfamiliar with the terminology and concepts bandied about in the field will find the presentation hard going, but if you've been keeping up with NASA's and other people's plans, then you shouldn't have any trouble following the thread of argument.

Astronomy: from the Earth to the Universe

by Jay M. Pasachoff

476 pages, paperback, no price given
W. B. Saunders (1979)

This text is intended for non-science students taking a college-level astronomy course. It is a modified version of the same author's **Astronomy Now**, the main difference being this book's strong emphasis on historical background. The illustrations are plentiful.

Enterprise

by Jerry Grey

288 pages, hardcover, \$10.95
Morrow (1979)

The author of this somewhat unusual history of the Shuttle project was a behind-the-scenes participant in much of the space technology development during the last two decades. As a result, his book on the history of the Shuttle is somewhat personality oriented, providing a look at events and people that normally never come to light in most books.

AstroNews

Venus and Earth: Engaged or Divorced?

Venus has provided astronomers with many puzzles over the years. Because of its perpetual cloud cover, little was known for certain about Earth's nearest neighbor planet until the era of

interplanetary space probes. Even the rotation period — the length of a venusian day — was a mystery until 1964, when the first radar observations capable of piercing the clouds were made.

The result, confirmed by subsequent observations, raised an even greater mystery. Venus rotates on its axis in a retrograde fashion (from east to west instead of west to east as does Earth and most of the other planets) and, more surprisingly, with a period of about 243 days. This figure is surprising because it is very close to one of the several "resonance periods" which would result from a gravitational link to Earth. A retrograde spin of exactly 243.16 days would mean that Venus, as seen from Earth, rotates four times on its axis between every inferior conjunction (when Venus is closest to Earth). Therefore, at each inferior conjunction, the same side of Venus would be facing Earth.

The values determined by a number of observations over the years have been so close to this resonance figure of 243.16 days that astronomers have been convinced that there is indeed some kind of gravitational lock between Earth and its sister planet. The problem has been that no convincing theory for the existence of such a lock has been found — theoretical calculations based on the masses, mass distributions, and distances of the two planets indicate that the forces involved are too weak to have resulted in a resonance.

Now three scientists have suggested that there is in fact no resonance lock at all. Writing in the June 1 issue of the *Astrophysical Journal*, Irwin I. Shapiro of the Massachusetts Institute of Technology, Donald B. Campbell of the National Astronomy and Ionosphere Center, and William M. DeCampi of Harvard University find convincing evidence that "Venus is not rotating with a resonance spin period." Their analysis of the radar observations accumulated over the years 1964 to 1977 enables them to fix the rotation period with considerable accuracy. They find it to be 243.01 ± 0.03 days. The $3\frac{1}{2}$ hour difference between this value and the resonance period of exactly 243.16 days, while very small, is statistically significant.

On the other hand, the researchers point out that the probability of Venus' rotation period falling by chance alone within one-fifth of a day of a resonance period is under 1%. Therefore they suggest that Venus could either now be evolving toward such a resonance, or was once in resonance in the recent past. Venus may not, after all, be married to Earth, but whether the two are divorced or engaged — and in either case, why — has yet to be determined.



Venus is seen passing inferior conjunction, photographed on eight consecutive days. Photograph courtesy of Yerkes Observatory.

Index

- Venus and Earth: Engaged or Divorced?
- Isaac Newton on La Palma
- Servicing the Space Telescope
- Cosmic Ray Observatory
- Recurrent Galactic Explosions
- Viking Visions
- A Supernova "Superscale"
- Extrasolar Planets and Life

Isaac Newton on La Palma

A new observatory complex that will rival Kitt Peak is being constructed on the Spanish island of La Palma in the Canary Islands, off the northwest coast of Africa. Its main instrument will be western Europe's largest optical telescope, the 100-inch Isaac Newton reflector, which is being moved from its current site at the Royal Greenwich Observatory in Sussex, England. At the end of May, Spain signed an agreement with several other European governments that will lead to the setting up of a new international observatory, called the Roque de los Muchachos Observatory, on the 8,000-foot summit of La Palma. Eventually, a new 165-inch reflector will be installed there by British astronomers.

The new observatory is particularly important to British optical astronomers. Their Isaac Newton telescope was set up in Sussex in 1967, but because of the English weather has been usable on average no more than about two nights a week. At its new site, it should be usable six nights a week. The telescope is being upgraded from its present aperture of 98 inches to a full 100 inches by the installation of a new mirror made of a special low-expansion material called Zerodur, replacing the old Pyrex mirror which was a gift from American astronomers in 1949.

In June, engineers from the optical firm of Grubb Parsons in Newcastle-upon-Tyne, who made the original telescope, removed it from its dome to begin installation of the new mirror and adapting of the telescope's drive to improve its pointing and tracking accuracy. Next year the improved Isaac Newton telescope should be shipped to La Palma, and it is expected to be in operation by 1982.

La Palma was chosen for the telescope site after many years of careful testing, including the islands of Madeira and Hawaii. La Palma turned out to have particularly clear, steady air, which is said to make it one of the best observatory sites in the world. As such, it has attracted the interest of other European nations.

Under the terms of agreement with their European colleagues, Spain is

providing an access road to the mountain summit and other services, while in return Spanish astronomers will be allowed 20 percent of observing time on the telescope.

In addition to the Isaac Newton telescope, a new British 1-meter telescope for photometry and astrometry is under construction by Grubb Parsons for the La Palma site, and there are plans to build a 165-inch reflector for deep-space studies. The mirror blank for this has already been purchased. This telescope will have an alt-azimuth mounting, like that of the Soviet 6-meter reflector.

Danish astronomers intend moving a transit instrument to La Palma for precise time-

keeping and measurement of star positions, and a group of European solar observers have earmarked the site for a major solar observatory. The whole complex is being termed the Roque de los Muchachos

Observatory, after the highest point on the mountain. As the observatory complex grows during the 1980s it will come to rival Kitt Peak in the number and importance of its telescopes. 

Cosmic Ray Observatory

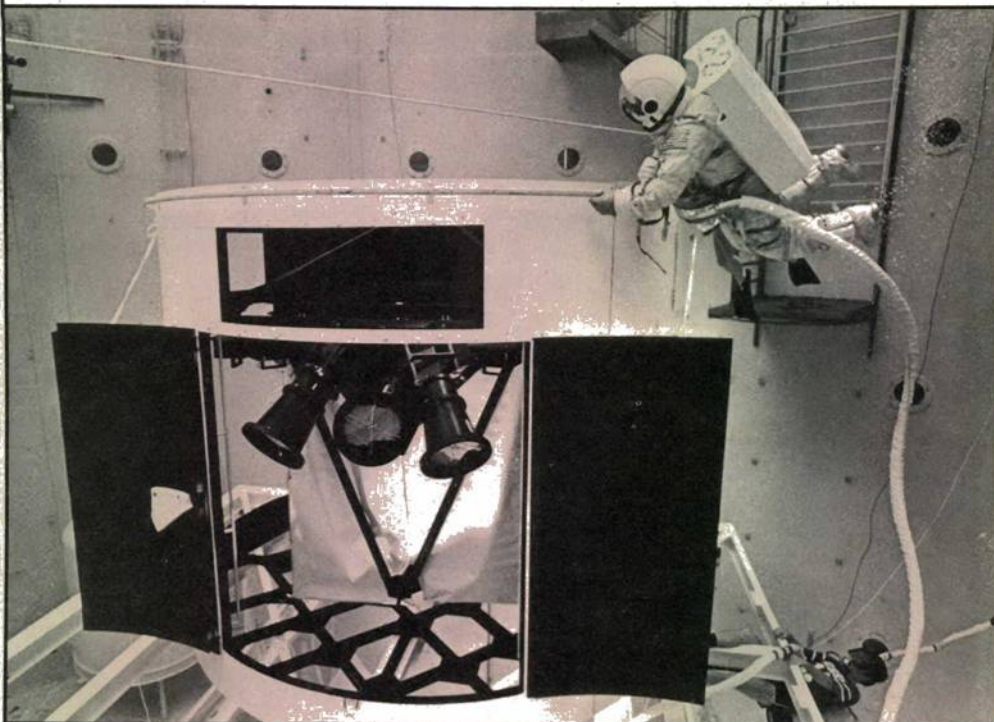
Sharp Laboratory at the University of Delaware is now the site of an observatory that keeps track of visitors from distant parts of the galaxy. But these aliens from afar are not intelligent beings of the "Close Encounter" genre. On the contrary, they are the most elemental form of matter — subatomic particles called cosmic rays. Mostly hydrogen nuclei moving at nearly the speed of light, they may wander through galactic space for millions of years

before reaching the solar system.

The 55-year-old Bartol Research Foundation of the Franklin Institute, which became affiliated with the University of Delaware a year ago, has a long tradition in cosmic ray research. The foundation's cosmic ray observatory was recently moved atop Sharp Laboratory, home of the department of physics and the Bartol Research Foundation. A rugged structure erected on

Servicing the Space Telescope

A pressure-suited astronaut works underwater in a huge tank, called a Neutral Buoyancy Simulator, at NASA's Marshall Space Flight Center in Huntsville, Alabama. Astronaut Bruce McCandless used the tank to evaluate methods and equipment which might be used to service the Space Telescope in Earth orbit. A full-scale mockup of a portion of the Space Telescope can be seen below McCandless. The Neutral Buoyancy Simulator, containing 1.3 million gallons of water, allows a close approximation of a zero-gravity environment. Among the tests which have been performed are ones to determine the difficulty of unlatching a door to the telescope's star trackers and other components and finding the optimum type and location of foot restraints and hand-holds. The underwater tests are conducted to decide what modifications, if any, are needed to permit removal and replacement of components in space, and the time needed for such tasks. The Space Telescope, scheduled for launch by the Space Shuttle in late 1983, can be retrieved while in orbit and positioned in the Shuttle Orbiter's cargo bay, where space-suited astronauts can service it as needed.



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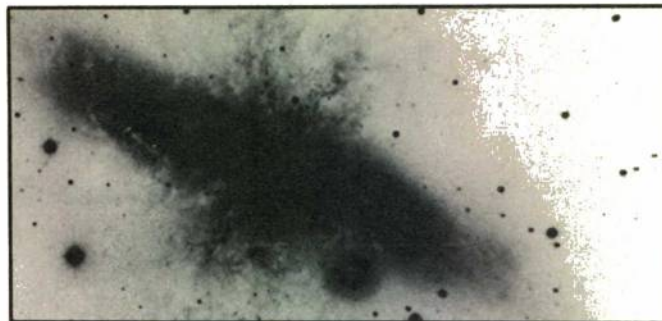
the roof houses the 20-ton detector, and the associated equipment is installed in a laboratory directly below.

With this installation, according to Dr. Martin Pomerantz, director of Bartol and principal investigator of the program, Sharp Laboratory has become the home base of a far-flung global network that literally extends from pole to pole. Field stations are strategically located in northern Greenland at Thule Air Base, on the coast of Antarctica at McMurdo Sound, and at the geographic South Pole.

The ground-based detectors at the different locations make it possible to study the ever-changing flow patterns of cosmic rays caused by the solar-controlled "weather" in interplanetary space, Pomerantz explains. On rare occasions (once a year on the average), he says, the Sun

briefly becomes the source of energetic nuclear particles with sufficiently high energies (in the billion volt range) to be detectable as cosmic rays at the Earth's surface.

The study of the Sun and its effects in space and on the Earth's upper atmosphere comprises a relatively new scientific discipline — solar-terrestrial physics. First, Dr. Pomerantz notes, cosmic rays serve as a unique tool for investigating exotic processes on the only star on which we can see surface features, our Sun. Second, they enhance our fundamental understanding of plasmas (gases composed of charged particles) by witnessing experiments performed by nature that cannot be contemplated in earthly laboratories. Finally, they are a part of the interplanetary meteorology that directly affects the Earth's environment. ☛



M-82 (NGC-3034)

Mount Wilson and Palomar Observatories

recurring explosions, events that happen every million years or so.

According to their report in the June 15 issue of the *Astrophysical Journal*, Gene Capriotti, Craig Foltz, and Paul Byard looked at massive clouds of dust and gas which lie very near the cores of these galaxies. "The clouds are very close to the center; we're pretty sure of that," Capriotti says. "They're somehow associated with the actual source of energy there."

Looking at the light spectra from the clouds, the researchers estimated material is moving outwards from the center at about 5000 miles per second — nearly one-thirtieth the speed of light. "There has to be a lot of activity taking place to generate that kind of motion," he says.

The three researchers looked at quasars and Seyfert galaxies, which are a class of active spiral galaxies. Elliptical galaxies are far more common in the universe. "We assumed that the clouds were enveloping a central source of energy. If they were 'thick,' light wouldn't pass through

them," Capriotti says. "The total brightness of the system of clouds would then be connected to the wavelength of the light by the Doppler shift and predictable spectral features would result." A computer plotted out graphs of the predicted light spectra.

There are only three strong possibilities, according to Capriotti, for what the clouds are doing. "They are either moving towards the center, moving away from it, or simply rotating around it."

They compared the actual spectral graphs to those produced by the computer. The graphs for a rotating system were "way off." Those for the contracting cloud systems that black holes would cause were not close. But the computer's graph representing the expanding cloud systems matched the actual observations extremely well.

"We think we knocked out one of the possibilities completely and, more than likely, got the other," Capriotti says.

What seems to be happening, the researchers explain, is that in opposition to the black hole theory, perhaps there is a recurring explosion every 100 million years or so. That works out to 100 times in the 10 billion year lifespan of a galaxy. The gravitational forces of the galaxy draw matter into the core area until it becomes unstable, literally blowing its top and taking about 10,000 years to cool off. Then new material would slowly be drawn into the center to repeat the cycle.

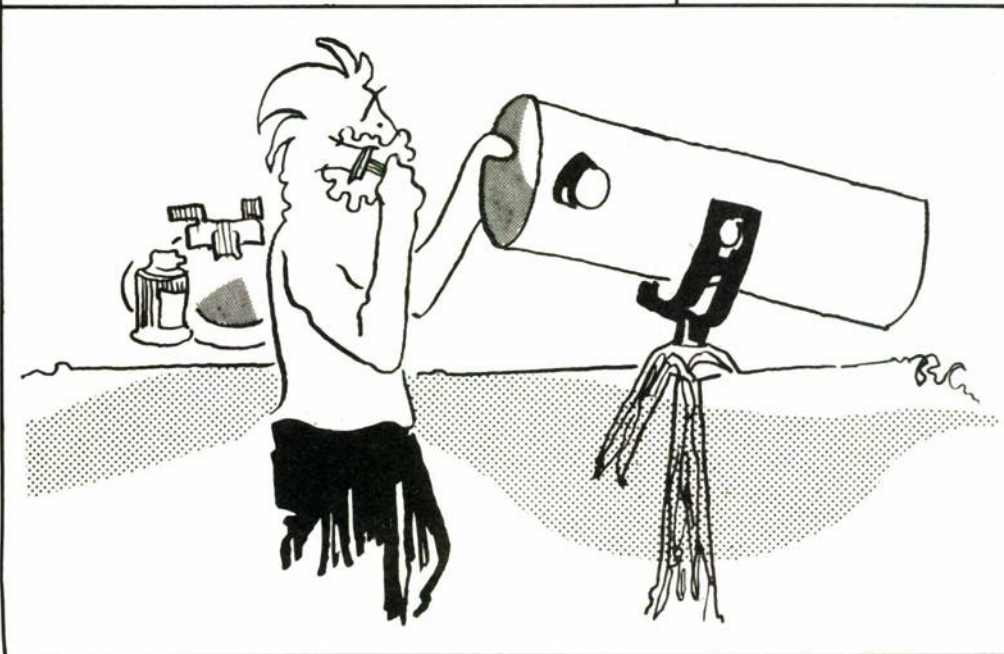
"Our theory doesn't rule out a black hole. It simply allows for the possibility of other things being involved in the galaxy's evolutionary process." He points out one nice thing about this theory: the non-active galaxies easily fit into the picture. They're simply in between explosions. "We're really just beginning our investigation. In the next year or so, we'll know if we are on the right track." ☛

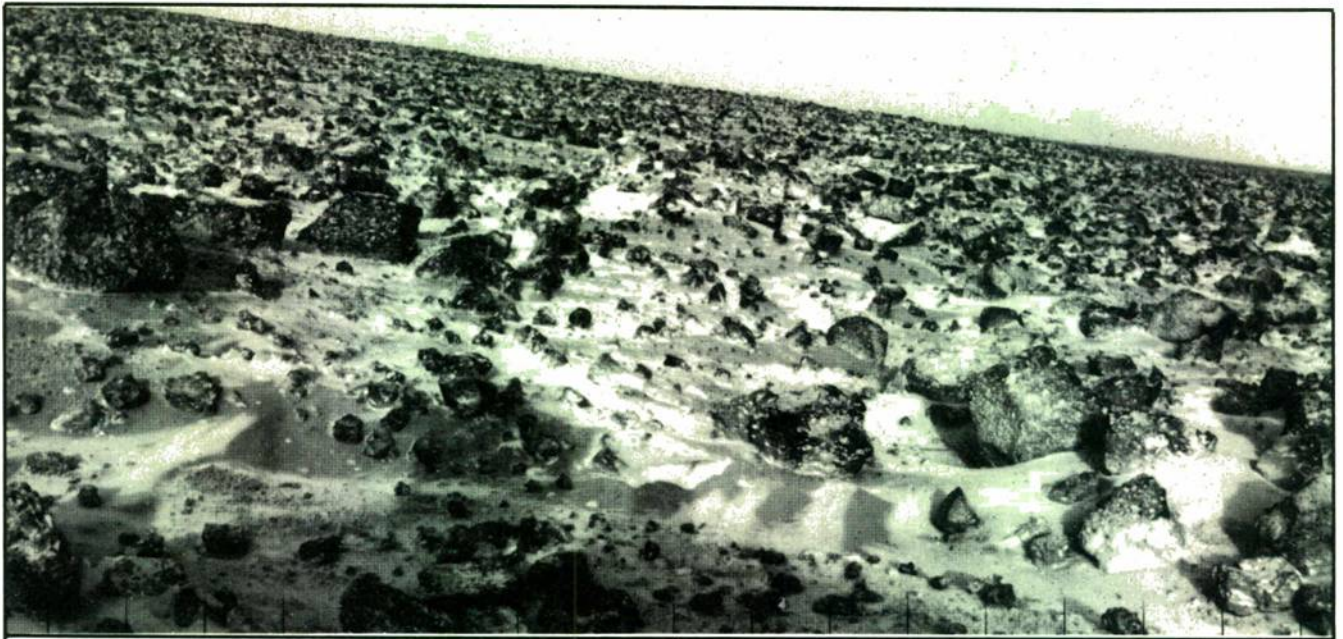
Recurrent Galactic Explosions

Astronomers have long known that something in the core of some galaxies emits more energy than hundreds of billions of stars — more energy than a normal galaxy emits as a whole. But just what that something is, isn't known.

The most popular theory is that the cores of "active"

galaxies contain black holes which gobble up everything within reach, generating enormous amounts of radiation in the process. But three astronomers at Ohio State University say this may not be the case. Instead of matter being pulled into the core, they propose that it's being flung outwards in gigantic,





Viking Visions

Three years after NASA's Viking spacecraft landed on Mars, scientists at the Jet Propulsion Laboratory (JPL) are still receiving data from one orbiter and two landers. The Viking mission has gone into a fourth major stage, called the Survey Mission, and the first data from that period have been received at JPL. The Survey Mission is scheduled to continue through 1990, more than 15 years after the spacecraft were launched.

Both Viking landers and the remaining orbiter are operating. The landers have been placed in an automatic condition that allows them to function unattended; Lander 1 transmits its information to Earth once a week.

Viking Orbiter 1 is taking high-resolution pictures of the martian surface with a clarity not obtained before, since the martian atmosphere has become unusually clear. (Viking Orbiter 2 was shut down July 24, 1978, after it ran out of attitude-control gas; Viking Orbiter 1 is expected to cease operations sometime in 1980.) Landers 1 and 2 continue to take pictures and to collect weather data.

Lander 2's cameras have revealed a new layer of water frost on the martian surface at the Utopia Planitia landing site. It is winter there again, and a thin layer of frost can easily be seen in the photos.

The new frost layer poses a scientific puzzle to members of the Viking team: in September 1977, Viking Lander 2 found frost on the

surface during the martian northern winter. (That was one martian year or almost two Earth years ago.) Scientists associated that frost collection with a major dust storm that had obscured the planet's surface before and during that period.

But recent observations have shown no dust storms on Mars this year — in fact, the atmosphere is clearer than scientists have seen it since Viking arrived in 1976. So no one is certain just what triggers the appearance of frost.

This much is believed: dust particles in the atmosphere pick up bits of solid water (ice). That combination is not heavy enough to settle to the ground. But carbon dioxide, which makes up 95% of the martian atmosphere, freezes and adheres to the particles and they become heavy enough to sink. Warmed by the Sun, the carbon dioxide evaporates and returns to the atmosphere, leaving behind the water and dust. The resulting frost layer may be only one-thousandth of an inch thick.

Viking 1 was launched August 20, 1975, and arrived in Mars orbit June 19, 1976. Viking 2 was launched September 9, 1975. It reached Mars August 7, 1976.

Viking Lander 1 touched down on the Chryse Planitia July 20, 1976, while Lander 2 followed Lander 1 to the surface on September 3, 1976. The planned lifetime for the spacecraft was 90 days after landing. ☛

This high-resolution photo of the surface of Mars was taken by Viking Lander 2 at its Utopia Planitia landing site on May 18, 1979, and relayed to Earth by Orbiter 1 on June 7. It shows a thin coating of water ice on the rocks and soil. The time the frost appeared corresponds almost exactly with the buildup of frost one Martian year (23 Earth months) ago. Then it remained on the surface for about 100 days. Scientists believe dust particles in the atmosphere pick up bits of solid water. That combination is not heavy enough to settle to the ground. But carbon dioxide, which makes up 95% of the Martian atmosphere, freezes and adheres to the particles and they become heavy enough to sink. Warmed by the Sun, the surface evaporates the carbon dioxide, leaving behind the layer of water ice and dust. Photograph courtesy of NASA/Jet Propulsion Laboratory.

A Supernova "Superscale"

In a distant region of space, a dying star thirty times as massive as the Sun suddenly explodes, outshining entire galaxies of billions of stars. It then fades in brightness, its final fate — neutron star or black hole — decided by how much of its mass was blown away to drift off into space.

Supernovae, or exploding stars, are studied not just because they are immensely powerful, and still largely mysterious, but also because they may provide a way to discern the ultimate fate of the universe. Astronomers know that the universe has been expanding for fifteen billion years, the galaxies rushing away from each other more quickly the greater the distance between them. But will they always retreat or will the expansion slow down, even stop, as precursor to reversal and final collapse?

To detect a slowing down of the expansion, astronomers must know the distance and velocity of recession of distant galaxies. Velocities are

obtained fairly accurately by measuring the Doppler shift, or reddening of light from the galaxies, but distances are much more difficult to establish.

Astronomers would like to use supernovae to measure distances to the galaxies where the supernovae are found. Supernovae are exceedingly bright, and so are visible at great distances. Unfortunately, they don't shine with the uniform brightness needed for astronomers to use them as "standard candles" — objects of known brightness whose distance can be determined by comparing that brightness with the brightness they appear to have.

Three astronomers, Stuart Schurmann and W. David Arnett of the University of Chicago, and Sydney Falk of the University of Texas, have devised a new method for measuring the distances to supernovae that seems to avoid some of the complications and inaccuracies of

AstroNews

earlier methods. Using the computer models of Arnett and Falk, Schurmann deduced distances to several supernovae without relying on the numerous and complex methods traditionally used.

His approach is unusual in that a computer provides some of the qualities of the supernovae that are usually obtained through lengthy observations. The technique, reported in the May 15 issue of the *Astrophysical Journal*, involves measuring the color of light emitted by supernovae as they grow dimmer, and comparing that color with the color predicted by computer models of supernovae. When the colors match, the brightness of the real supernova is assumed to equal the brightness of the computer model. The supernova's distance is then determined from a well-known astronomical formula that requires only that the supernova's apparent and actual brightness be known. Knowing the apparent brightness of the supernova from telescopic observations and having the computer's prediction of the supernova's actual brightness, Schurmann quickly calculated its distance, making allowances for the effects of dust clouds between the supernova and Earth.

Schurmann says he didn't know what to expect from the method, but as with any new approach in science, the value of the method is established by comparison of prediction with observations. Schurmann's distances match those obtained with traditional methods almost perfectly. This

is important not just for what it says about the accuracy of the computer models, but for the distance measurements it may make possible in the near future.

"Knowing the distance to a supernova means knowing the distance to its parent galaxy," says Schurmann. "By comparing the distance of a remote galaxy with the rate at which it is receding from the Earth, it is possible to detect any changes in the expansion of the universe."

Supernova and galaxies are presently the only two kinds of objects both bright enough and readily enough measured at various distances to serve as distance indicators far out in the universe. Supernovae may be better because galaxies can change brightness as they age, making them unreliable indicators. Schurmann claims that with the advent of the space telescope in 1983, his technique could be used to measure supernovae distant enough to be affected by the so-called "deceleration parameter," the measure of the rate at which the universe's expansion is slowing down. The deceleration parameter must be less than one-half if the universe is to avoid crashing in upon itself in the final cataclysm of all time.

Fifteen billion years of history have passed since time began with the Big Bang. Within the next five years, with the application of new techniques in astronomy, man may know the fate of the universe for the rest of time.



Extrasolar Planets and Life

Contemplating the stars, the 19th century philosopher Thomas Carlyle dismally observed: "A sad spectacle. If they be inhabited, what a scope for misery and folly. If they not be inhabited, what a waste of space." More recently, a number of scientists met this past June at NASA's Ames Research Center in California to discuss the latest evidence on the possibility of intelligent life on other worlds, and it was clear that the question of whether or not man is alone in the

universe is hardly closer to being answered today than it was in Carlyle's time.

Although several careful and interesting studies have been made as to the probable number of extraterrestrial civilizations presently extant in the universe, any such speculation must rely on a certain number of untested assumptions. Among the various unknown factors affecting the possibility of otherworldly life and/or intelligence, one of the most crucial is the number of

planets outside our solar system. While many of the researchers meeting at Ames debated such esoteric topics as the probability of life forming spontaneously, the odds of life evolving into intelligent forms, and the chances of a technological civilization surviving for a significant period of time, Dr. David Black of the Ames Research Center was careful to point out that astronomers have yet to discover a single planet outside our own solar system.

Indeed, at the beginning of this century it was theorized that our solar system was the result of a freakish cataclysm in which the planets formed from matter yanked out of the Sun by a passing star. At that time, the prospects for extraterrestrial life outside the solar system looked pretty grim because if this theory of planetary formation were correct, only a lucky handful of suns throughout the entire galaxy would possess any kind of planets, much less those capable of harboring life. Our picture of the universe changed by the 1930s and planets are now thought to be formed alongside their parent star from the same cloud of gas and dust. Given the accuracy of this model of stellar and planetary formation, the universe should be teeming with other worlds, a portion of them inhabitable if not already inhabited.

A 1964 Rand Corporation study, *Planets for Man*, estimated that there are 600 million potentially inhabitable planets in our galaxy. Here "potentially inhabitable" refers to the environmental limits of human beings, fairly fragile creatures whose bodies have evolved to sustain the rigors of a particular planet. The endurable range of conditions is presumably much greater for life at its most flexible.

Recently, Michael H. Hart has employed computer calculations to argue that studies like Rand's are far too liberal in their estimates of habitable zones around stars (see "Uninhabitable Stars," *AstroNews*, *ASTRONOMY*, July 1979).

Nevertheless, the issue is far from settled. For instance, Hart asserts that if Earth's orbit were 1% larger, "runaway glaciation" would have frozen all the planet's water 2 billion years ago. Crucial to the argument is the assumption that there were land masses surrounding at least one of the poles to insulate the ice

from sea water and keep it from receding each summer. Isaac Asimov points out, however, that a landlocked North Pole is only a recent state of affairs resulting from continental drift and tentatively judges that "the asymmetry of continental arrangements has allowed a succession of Ice Ages only during 1% of Earth's history" since either pole becomes land only about once every 250 million years. On planets with even less land area than Earth, the chances of complete glaciation would be reduced even further. Ironically, Dr. Asimov feels that Earth was quite lucky to be graced with its Ice Ages because many consider that the climatic stresses accompanying them were an instrumental factor in the rapid evolution of man's intelligence.

Specialists at the recent Ames meeting heard Dr. Robert S. Harrington of the U.S. Naval Observatory report on other computer simulations which demonstrated the possibility of life-bearing planets following stable orbits in many multiple stars. Previously, double and multiple stars, constituting at least half of all stars, were considered inhospitable systems for fertile planets.

While debate about the actual number of habitable planets is helpful and serves to clarify physical possibilities and the resulting planetary scenarios, the argument remains open and speculative until concrete evidence for the existence of extrasolar planets comes to light.

Attempts to discover nearby planetary systems to date have yielded only a few positive indications and even those are regarded as highly dubious. Direct observation of extrasolar planets is out of the question for Earth-based telescopes, since even a planet the size of Jupiter would be lost in the glare of the nearest star. The only chance earth-based astronomers have of detecting extrasolar planets involves looking for slight perturbations in a star's path as it moves through space. A star possessing a heavy planet should be pulled off course ever so slightly as the smaller mass swings around it, somewhat like an elephant waltzing with a gnat. While in theory the method sounds good and, after decades of painstaking search, Peter van de Kamp and others claim to have discovered several

examples of "dark companions" attending nearby suns, most notably Barnard's star, it now appears that these observations are too full of instrumental errors to be significant. After all, the measured size of such perturbations is about equal to the angular diameter of a hair as viewed from one mile.

Though Earth-based telescopes seem to be out of the picture, the Ames Research Center has conducted studies which offer some exciting possibilities for planet detection using special instruments in space. According to the testimony of Bernard Oliver of Hewlett-Packard Corp. (co-chairman of the Project Cyclops Study) before the House Subcommittee on Space Science and Applications concerning Extraterrestrial Intelligence Research, two different schemes might be used to detect other solar systems. One method involves pointing the axis of a spinning infrared interferometer along the line of sight to a star, causing any planet near it to appear to orbit at high speed. A planet passing in and out of the fringes of the interferometer would produce a

modulation in the output signal. The modulation should be most detectable in infrared because at that wavelength the planet would be at its brightest relative to its stellar sun.

The second approach would require a specially designed space telescope whose objective would reduce diffraction to a minimum. Since extrasolar planets cannot be viewed from Earth because they are outshined by the stars they orbit, the best strategy for direct observation is to construct a telescope which does not scatter the starlight into a planet-obscuring disk. According to Dr. Oliver, "If the light transmission of the telescope is tapered smoothly to zero at the rim — rather than remaining clear to the rim and suddenly dropping to zero — the diffracted light is greatly reduced. In principle this would allow Jupiter to be seen, in spite of the glare of the Sun, by an observer 30 light-years away, using only a two meter telescope." Instead of requiring observation of 2 or 3 complete orbits of the planet for confirmation, this method could confirm a planet's presence after only

three exposures during one-fourth of an orbit, using 2 or 3 years of observing time rather than 20 or 30. One advantage of direct imagery is that colorimetry of the planet might be possible. Theoretically, it could even be possible to detect the blue of oceans and the green of vegetation which would indicate some kind of life-bearing planet.

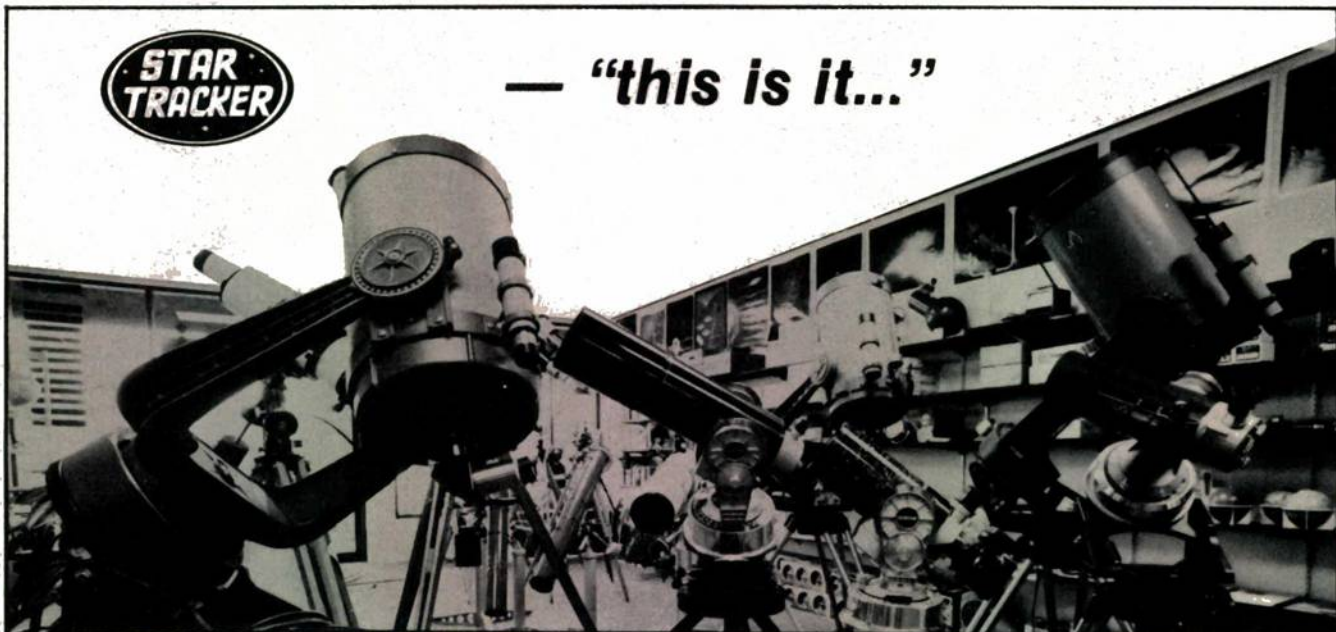
Although a tapered transmission mirror might not be generally desirable as a permanent fixture, the same effect could be produced by temporarily placing a special filter across the aperture of the already planned Space Telescope during a rendezvous with the Space Shuttle. According to Dr. Noel Hinners, the former NASA Associate Administrator for Space Science, even the unmodified Space Telescope has a chance of detecting the presence of Jupiter-size planets around the nearest 40 to 50 stars — those within a radius of approximately 15 light-years. However, due to the lack of a test chamber capable of duplicating the complete absence of stray light unique to the space environment, no one knows

exactly how well the Space Telescope will perform in terms of light diffraction.

Dr. Oliver doubts that either a spinning infrared interferometer or tapered transmission telescope could observe planets orbiting any but the nearest 100 to 200 stars and considers it possible that we could only detect giant planets like Jupiter or Saturn which do not appear favorable to the emergence of life. Nevertheless, confirmation of the existence of such giant planets could still prove that planet formation is a non-cataclysmic process, raising the likelihood of smaller, more Earthlike worlds. Moreover, just the sight of extrasolar planets might spur the government into creating more aggressive programs to search for extraterrestrial intelligence. Two million dollars allocated for such a search was cut from NASA's 1979 budget, and no new requests are planned before 1982. According to Dr. Robert Edelson of the Jet Propulsion Laboratory in Pasadena, California, a modest program would cost about the same as the movie *Close Encounters of the Third Kind*.



— "this is it..."

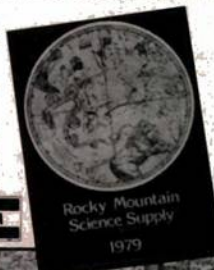


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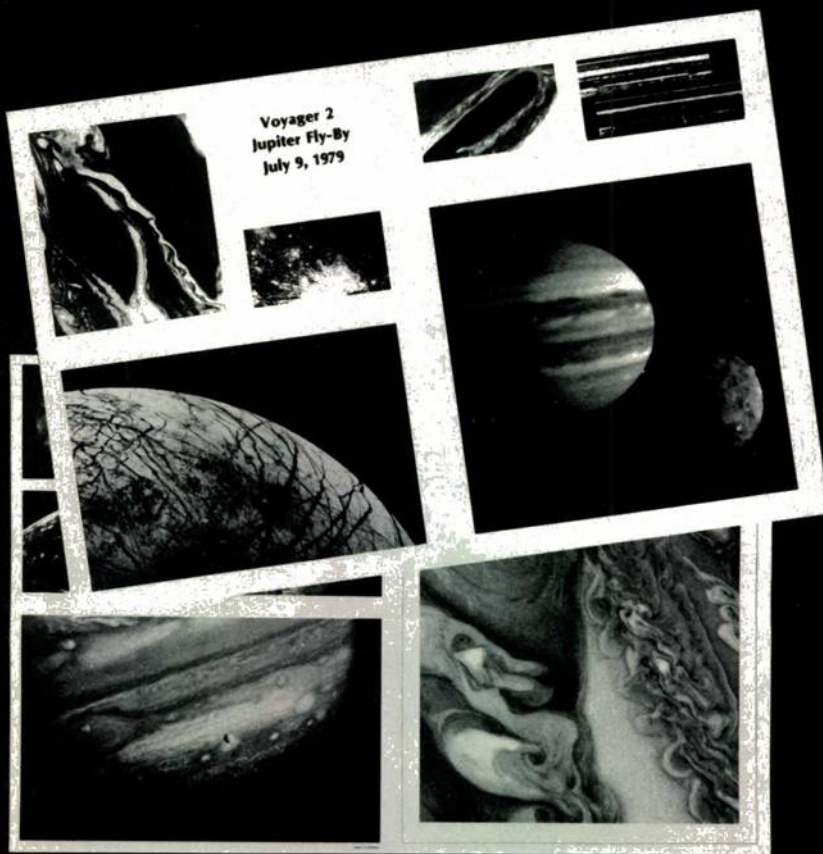
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The Cosmological Principle

by
Paul S. Wesson

The Cosmological Principle, in its familiar form, says: "The universe looks the same to all observers regardless of where they are located." As such, it sounds like a plausible basis for theoretical models of the universe. And it's reassuring, too, for it means we live in a typical part of the universe.

But plausibility alone is not enough to assure the usefulness of a principle which underlies much of modern cosmology. Why then, was it accepted for so long? What lay behind its formulation? In what ways does it fail as a useful principle for modern cosmology?

The Cosmological Principle was needed in the first place to have a rule on which to base models of the universe. "The universe looks the same to all observers regardless of where they are located," in effect, is a rule about the distribution of the galaxies in space. With a good-size telescope you can see quite literally millions of galaxies. They come in various types and sizes, but the important thing is that they appear to contain most of the matter in the universe.

Astronomical observation confirms this. There may be more matter tucked away somewhere in the Milky Way and other galaxies that we can't see or detect with telescopes because it is dark and cold. Some matter, perhaps a great deal, may surround galaxies in the form of massive dark halos, and the cores of galaxies may harbor giant black holes. But none of these possibilities alters the basic fact: the mass of the universe is found mainly *in or around* galaxies. Thus, the Cosmological Principle says that the matter in the universe is distributed evenly, because no matter where you are, you'll see the same number of galaxies.

Cosmologists make models of the universes with the known laws of physics; they use mathematical expressions to describe them. Physics, however, actually allows too many possible "universes" all different from each other. To find a model — that is, a set of equations — which accurately reflects the nature of the real universe (i.e., the one we live in), cosmologists must place limits on the general physical equations. The limits narrow down the number of theoretically possible models and also often simplify the job of solving the equations.

Of these limits, the Cosmological Principle is the most fundamental.

It was formulated in order to provide a rule for the mass distribution and certain other properties of the universe. It looks good on paper and is satisfying because

it prevents humanity from occupying a favored place in the general scheme of things. Moreover, it's simple.

While the approach was certainly a practical one, ironically the main problems that have arisen with it have been due to the failings of human beings rather than the observational evidence. For example, one of the first confusions to arise was the specific mathematical form the Cosmological Principle ought to have. E.A. Milne, in a 1940 paper in the *Astrophysical Journal*, was the first astronomer to construct a concrete cosmological principle. His formulation was wide in scope, definite in content, and based on the mathematical group theory. He argued that a model universe obeys the Cosmological Principle if observers located anywhere can give mathematically equivalent descriptions of the statistical properties of the particles (galaxies) it's made from.

Milne was trying to find a rule that would allow all observers to describe the universe in the same way if they were equipped only with a clock for measuring time and a device to measure distances. The details of Milne's cosmological principle are mathematical, and make use of the technique known as *dimensional analysis*. This technique allows mathematicians to find relations among physical variables using only the knowledge of how those variables depend on the fundamental quantities of mass, length, and time.

The mathematics involved is easy by modern standards, but it seems to have been indigestible for the astronomers of Milne's day. Instead of using the full power of his hypothesis, they adopted the idea behind it in a disappointingly watered-down form.

Thus to most astronomers today, the Cosmological Principle means that the universe looks the same to all observers because the density of the galaxies is the same at all places. This is consistent with what Milne wanted to do, but is very much weaker. For example, it specifies the density of the matter in the universe but makes no mention of any other property of that matter such as its pressure or velocity. While it's true that given a uniform density you can deduce certain other properties of the matter distribution, you can do this only by bringing in other physical laws which should not to be included in something as fundamental as a "Principle." Thus, the modern understanding of the Cosmological Principle is so weak that it's doubtful it even deserves the name.

When the Russian cosmologist Aleksandr Friedmann developed mathematical models of the



universe using Einstein's general theory of relativity many years ago, he based them on the assumption that the density of galaxies is uniform. Einstein's theory is a complex theory of gravitation which, in the case of weak attractions, simplifies to the classical Newtonian law of gravity. Einstein's theory is a successful one, so far, but this doesn't necessarily mean that the special "Friedmann models" based on general relativity must be valid. In fact, only in the case where the density of the universe is uniform will the Friedmann models agree with observation because they assume the validity of the old Cosmological Principle. If general relativity is true, then any failure of the Friedmann models implies a failure of the old Cosmological Principle.

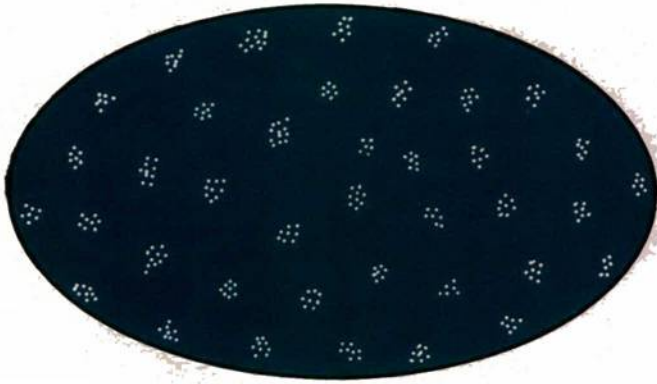
Recent astronomical observations show that the Friedmann models are running into trouble. The main problem is that the galaxies of the real universe aren't distributed uniformly throughout space. They're clumped together in clusters and clusters of clusters. The "clumpiness" means that the Friedmann models depart from observation in our neighborhood of space.

A rich cluster of galaxies, such as this one located in Perseus and pictured above, may be as much as 10 million light-years across and contain hundreds or even thousands of individual galaxies. Such clusters, astronomers suspect, may themselves be members of even larger superclusters. Such "clumpiness" on a cosmic scale would have profound implications for modern cosmological theories. Photograph by N.T.H. Lermann.

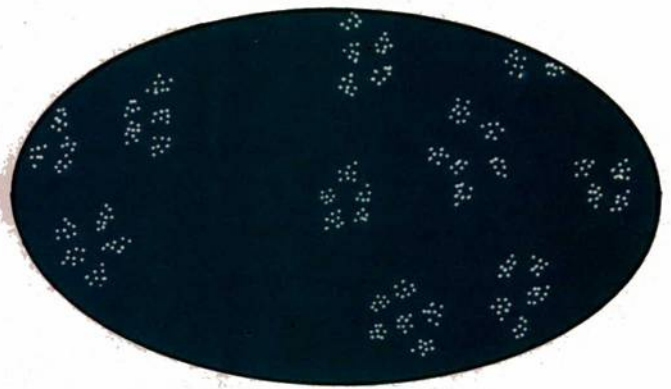
More importantly though, the observations immediately contradict the assumption of uniformity. The seriousness of this depends on how widespread the clumpy distribution of the galaxies is. If the clumpiness is small-scale, then the universe as a whole will still be pretty uniform, and the Cosmological Principle would be all right. But if the clumpiness is very, very large scale, then the universe as a whole wouldn't be uniform.

How big, in other words, can clusters of galaxies be?

A typical "rich cluster" in the constellation Perseus is undeniably BIG: about 10 million light-years in total diameter. A "supercluster" in the constellation Corona



We know that the billions upon billions of galaxies in the universe are grouped together in clusters of various sizes. Until recently, astronomers believed that these clusters were randomly distributed throughout the cosmos, with no larger organization.



Now, however, some observational evidence indicates that there may be a hierarchy of clusters, with the individual clusters of galaxies grouped into larger superclusters and perhaps even cosmic clusters of superclusters. If true, this large-scale structuring of matter in the universe would profoundly affect cosmological theories.

Borealis is about 100 million light-years in diameter. (The diagram on page 69 shows how the supercluster is composed of smaller clumps.) The clumps in the Corona supercluster — of which there are about a dozen — are themselves clusters of galaxies, each of which consists of smaller associations of galaxies.

Naturally the question arises: Are superclusters themselves members of super-superclusters? Recent research shows that clusters as large as 2 billion light-years across exist. For comparison, the part of the universe that we can see is about 40 billion light-years in diameter, and there's even some evidence for clumpiness on that scale. Anyone might be forgiven for being skeptical of the Cosmological Principle when presented with results like these.

The Friedmann models with uniform density also have other problems well-known to cosmologists. One is a large discrepancy between different ways of calculating the density of galaxies in these models. Another is that too many galaxies and quasars seem to be found at great distances from us. A third is that the Friedmann models fail to explain how the galaxies we observe came to be formed in the first place.

Despite such shortcomings, many astronomers

haven't considered these faults by themselves sufficient to warrant abandoning the Cosmological Principle. They feel that each of these problems can be adequately explained by astrophysical causes, and the underlying assumption of uniformity can remain unchanged. But the Cosmological Principle, at least in its old form, besides being observationally suspect, is also logically flawed to an extent that makes it practically worthless.

Let's examine the statement of the traditional Cosmological Principle again: "The universe looks the same to all observers regardless of location." What does this really mean?

Taken at face value it means, among other things, that the universe should look the same to an observer who has eyes sensitive to ultraviolet light as it does to one who has eyes sensitive to infrared light. But these observers can readily see that the universe is *not* like this: stars, and galaxies composed of them, don't look the same in ultraviolet light and infrared light. The two views are even more dissimilar for X-rays and microwaves — and bear almost no resemblance to each other for gamma-rays and radio waves.

Well, you might say, what a CP really describes isn't how the galaxies *look* at different wavelengths of the electromagnetic spectrum, but how matter is distributed in them, regardless of how that matter is observed. Yes, this is true. But how, in practice, would you measure the amount of matter inside a given volume of space so that you could compare it with the amount of matter in some other volume of space?

This question is not as easy to answer as it might appear. You can't simply weigh the matter concerned. Apart from practical problems (i.e., finding a balance big enough to accommodate a galaxy), you don't know how that balance is affected by gravitational fields everywhere present in space, and which vary from place to place. Whatever you do, you'll have to take into account all possible distortion of your apparatus and all possible sources of mass.

For example, you can't calculate the mass of a cluster of galaxies by measuring its light output, dividing by the light output of the Sun, and saying: "This is the mass of these galaxies in solar masses." This just doesn't work: you don't know if all stars radiate as strongly as the Sun, or even if all the matter involved is present in the form of stars.

There is, in fact, a way to measure mass and to compare its values at different places, but it can only be done by expressing the mass in combination with other variables. In a universe like ours, where the distribution



of the galaxies is dominated by gravity, and observations are made by electromagnetic waves, the question of how you measure mass cannot be divorced from the physics involved. For our universe, the physics of gravity depends on the Newtonian gravitational constant and the physics of electromagnetic waves depends on the velocity of light; the only foolproof way of measuring mass is to evaluate the so-called Schwarzschild factor of general relativity theory.

This quantity is made up of mass (m), the Newtonian gravitational constant (G), the velocity of light (c), and a unit of length (l):

$$Gm/c^2l$$

The Schwarzschild factor is dimensionless. Although it is composed of the fundamental quantities — mass, length and time — with which all physical parameters can be expressed, it *does not itself have any units*. You could change the mass unit from kilograms to grams, ounces, barleycorns, or whatever you want. But because G also depends on the unit you use, the change in the units in m cancels with the changes of unit in G . Whatever units you choose for length and time (armspans, inches, or miles; seconds, heartbeats, or centuries) also cancel out completely. The result is that the Schwarzschild factor is the same no matter what units are used.

As far as cosmology is concerned, the use of dimensionless numbers ensures that our measurements of the properties of galaxies are well-defined in terms of the operations we must actually carry out to measure them. In contrast to this, the assertion of the old Cosmological Principle (that the density is the same everywhere) is not well-defined because we don't know what we must do to prove it. There is no meaningful way astronomers can test this assertion by astronomical observation.

What ought to be the basis of the Cosmological Principle? If we could use dimensionless numbers, we would gain two advantages. First, because they are dimensionless, we would know that we haven't introduced any human-invented units or scales into the theory. Second, we know that these numbers are related to measurements that can be made without risk of ambiguity.

But can we construct a "Dimensional Cosmological Principle?"

Indeed we can, and the basic idea is simple.

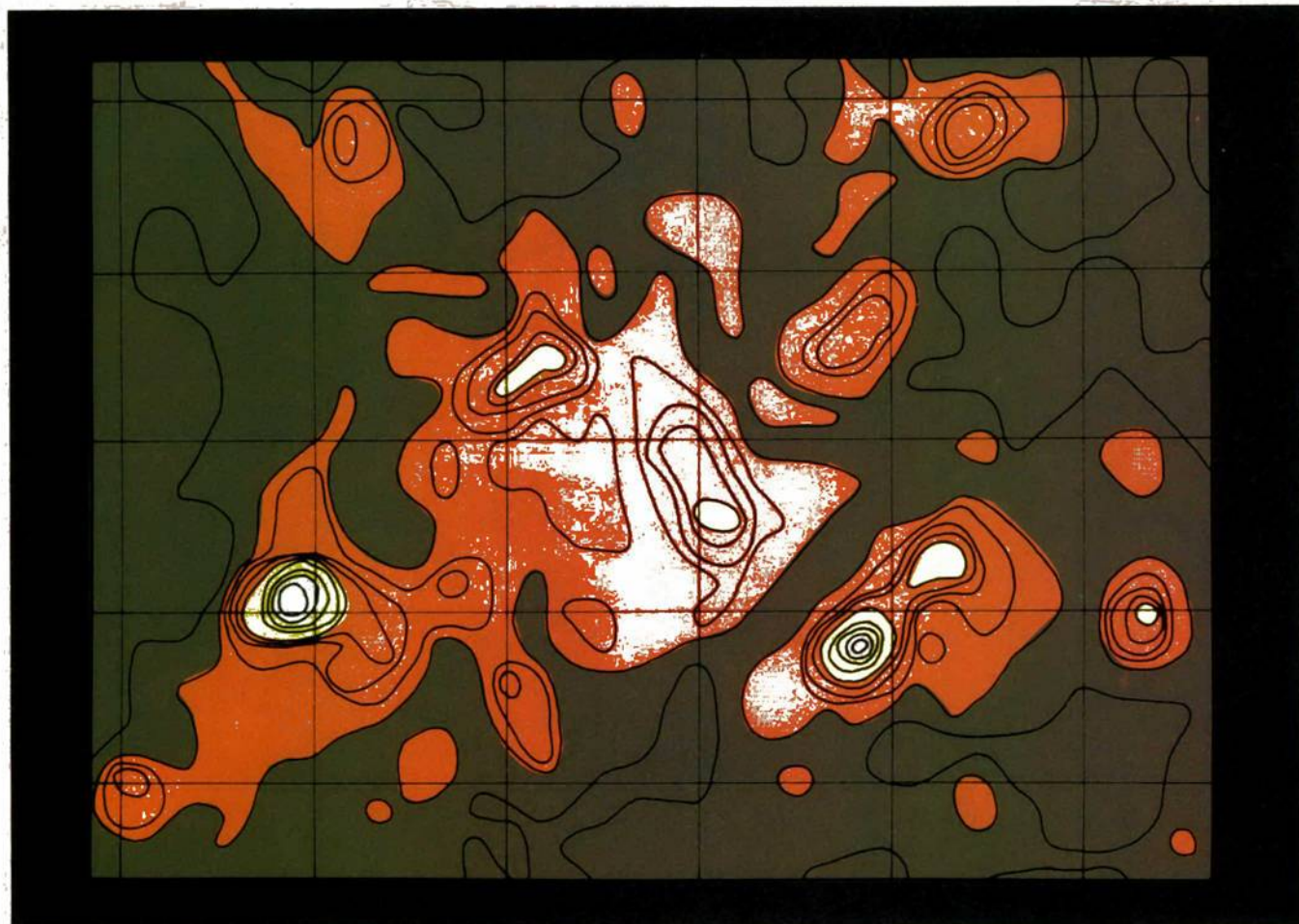
Cosmology deals primarily with several properties of matter in the universe: density (ρ), pressure (p), and mass (m) within some region of space of length (l). The quantities ρ and p can vary with l from place to place in a clumpy universe, and l is related to how the particular model of the universe expands with time. We must also remember that physics requires us to incorporate the constants for gravity (G) and the speed of light (c).

Now we have everything we need, and it isn't too difficult to find a way of combining the six parameters, ρ , p , m , l , G , c , into dimensionless numbers. The best choices turn out to be the three numbers:

$$\begin{aligned} 8\pi G l^2 \rho / c^2, \\ 8\pi G l^2 p / c^4 \text{ and} \\ 2Gm / c^2 l \end{aligned}$$

The last dimensionless number is the familiar

The diagram below shows the density distribution of galaxies in the Corona Borealis supercluster. This supercluster spans about 100 million light-years and includes at least a dozen lesser clusters, each of which consists of even smaller associations. Some astronomers speculate that the entire observable universe, 40 billion light-years in diameter, may constitute a "local" super-supercluster.



Schwarzschild factor. (The pure numbers 8π and 2 are just introduced for numerical ease and are of no significance in themselves.) We now have a Dimensionless Cosmological Principle that asserts, simply, that these three dimensionless numbers do not depend on location in the model universe.

We can even go one step further and improve on the Perfect Cosmological Principle (proposed by Bondi, Gold, and Hoyle) which in its old form said that the universe should not only look the same at all places but do so at all times in its history as well. The hybrid Dimensional Perfect Cosmological Principle simply states that the three dimensionless numbers should be the same at all places at all times.

The choice of whether you are satisfied with the Dimensional Cosmological Principle, or would like to adopt the even stronger Dimensional Perfect Cosmological Principle, is philosophical and is up to you. (Even cosmologists have to take a personal stand at some point.)

However, if it's to have real meaning, any cosmological principle has to be useful. It ought to provide us with cosmological models that are realistic — for example, its use ought to enable cosmologists to find new solutions to Einstein's field equations of general relativity. It would also help if there was some overlap with the old Cosmological Principle so that cosmology won't be faced with the daunting task of demolishing and then rebuilding its entire mathematical structure.

And it does. All of the familiar Friedmann models of the universe obey the Dimensional Cosmological Principle. This means that most of the cosmological research which has been carried out to date is safe from criticism and can still be used. It gives new solutions to Einstein's equations, solutions which describe inhomogeneous models of the universe, models in which

galaxies are clumped together into clusters of unlimited size.

The "Perfect" version, which says that the universe should be describable by dimensionless numbers which are the same at all places and at all times, also turns out to be useful. Applying this even more stringent condition to the uniform Friedmann models gives new solutions to the equations. And it just so happens that one of these new solutions describes mathematically a distribution of galaxies which is similar to the distribution actually observed.

The Dimensional Cosmological Principle came about because the old ideas conflicted with the rapidly-growing body of observational evidence indicating that galaxies in the universe have a clumpy rather than a uniform distribution. It now extends the basis of cosmology by providing a definite statement (that the universe can be described in terms of dimensionless numbers) in place of a vague assertion that the universe "looks the same" at all places. If it's wrong, it will certainly be much easier to prove wrong; "looks the same" is rather open to interpretation.

It will be interesting to see in the future how cosmologies based on the new Dimensional Cosmological Principle fare in dealing with the problems that troubled the old cosmology. We might even find a model based on the stringent Dimensional Perfect Cosmological Principle which agrees with all of the available astronomical observations. Who knows, we might be living in a Perfect universe after all!

*Paul S. Wesson has done research in gravitation and cosmology at London and Cambridge Universities in England and Queen's University in Canada. In 1978 he received a Royal Society Research Fellowship. His paper, "A New Look at the Cosmological Principle," on which this article is based, appeared in the journal *Astronomy and Astrophysics*, vol. 68 (1978), pp. 131-137.*

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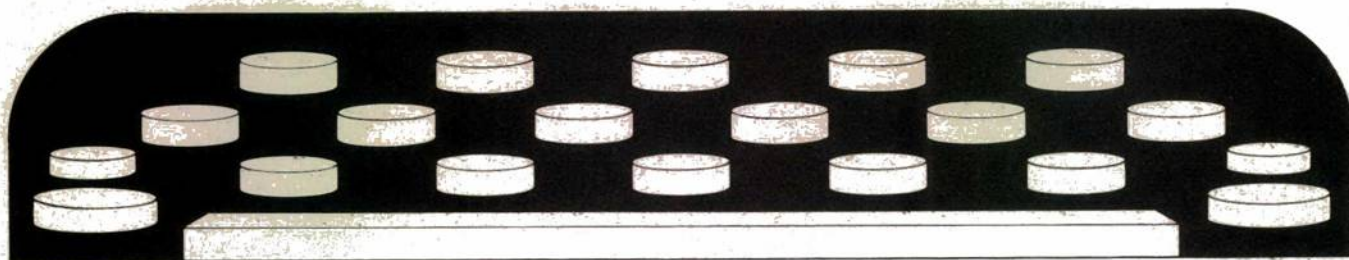
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IN FOCUS

Sir / I, like most people, was simply amazed and very delighted at the pictures and images returned by the Voyager probe to Jupiter. The pictures in the May 1979 issue are fascinating beyond belief. The details and colors of the features of the atmosphere of Jupiter, plus the fact that the planet is 11 times the size of Earth, make Jupiter, in my opinion, far more interesting than Mars, or any other planet so far. Such an alien world, and so big! If we were living, say, 50 years from now, I'd want to be part of the first manned mission to explore Jupiter.

I have a question, however, that bothers me so much that I can't wait anymore to ask about it.

We all know that the atmosphere consists primarily of hydrogen, with some helium and some other gases, but almost all hydrogen. Isn't there a serious danger that we could ignite the atmosphere of Jupiter with just a single spark of flame from our probe? Or is an all-hydrogen atmosphere stable or inert enough to not even pose a problem like this?

J.F. Lambert
Burlington, MA

Mr. Lambert / An all-hydrogen atmosphere will not explode. Hydrogen is explosive when it's mixed with oxygen or other oxidizing gases — hence we regard it as dangerous. On Jupiter, where free oxygen is quite rare, you could burn an oxygen flame in the hydrogen atmosphere, certainly an interesting about-face from the terrestrial oxy-hydrogen torch!

Sir / It is clear from the recent Administration statements on energy that the satisfaction of energy needs is given very high priority, so high that all subsidiary concerns (environmental effects, special-interest preferences, etc.) will, if necessary, be subordinated by the Administration to meeting those needs. That being the case, it would be foolish of the astronomy profession to set itself up in opposition

to any energy technology that might ultimately be demonstrated the best choice on all other grounds. Clearly its interests would not take precedence over a perceived urgent national need.

At present, though, it is too early to say whether SPS will be feasible, acceptable, and economically competitive. However, I think astronomers would serve their profession far better by insisting that their interests be met in a possible SPS program, rather

than by engaging in a battle of opposition which they would surely lose.

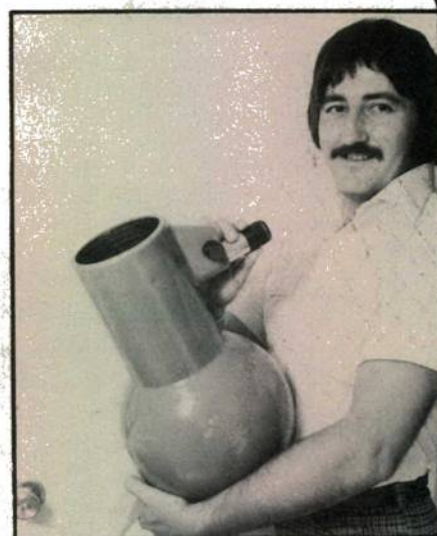
The profession of astronomy could gain greatly by astronomers' negotiating that in the event of an operational SPS program some tonnage — perhaps 1000 tons per year or more — of satellites lifted to orbit be in the form of optical and radio telescopes placed in much higher orbits than the SPS plants. That would result in a far

Behind the Scenes

**Another Winner! —
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We're up to our fourth Astroscan 2001 winner now (as soon as we get some pictures back from winners 2 and 3, we'll announce their names, too) and it's Mike Newcomb of North Ogden, Utah. Mike writes: "I am very thrilled at winning something for the first time in my life...especially a telescope. And for only renewing a magazine subscription that adds so much interest and pleasure to my number one hobby: astronomy My occupation is Art Director for Meridian Publishing Company, the world's largest publisher of company magazines...my main observing interests are double stars, planetaries, globulars and galaxies." Mike also adds: "Being in the publishing business, I can appreciate more than most, the quality and beauty of your magazine. Keep up the good work."

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Richard Berry

Richard Berry

higher quality and quantity of both optical and radio astronomy by professional and amateur astronomers than could ever be done from the Earth. The satellite construction and emplacement technology developed for SPS would, of course, be directly applicable to that scientific goal.

Gerard K. O'Neill
Professor of Physics
Princeton University

Sir / Your readers may be interested in further background on the July 1979 AstroNews article, "Instead of Man on Mars..." a commentary based on the 1975 NASA publication *Outlook to Space*.

Apollo, and its immediate — and closely related — successor Skylab taught the space agency that today's triumphs do not automatically signal support for tomorrow's follow-on ventures. Almost as amazing to many observers as the success of the lunar and space station endeavors, was the failure of a large-scale, post-Apollo/Skylab manned space flight effort to gel. The attempt to build major new missions, including a manned expedition to Mars, failed not because of lack of imagination and drive on the part of the space community, but rather because public support was diminished. And this was reflected by cooled-off attitudes in Congress.

A couple of months after the stunning success of Apollo 11, Associate Administrator for Manned Space Flight, George E. Mueller, reviewed some post-Apollo goals that had just been recommended by the Space Task Group to President Nixon. Noting that the Apollo program "had served our nation well in providing a clear focus for the initial development

and demonstration of manned space flight capabilities and technology," he went on to express the need for "a balanced program" that would provide for "the sustained development and use of manned space flight over a period of years focused on an eventual manned planetary landing in the 1980s." By "planetary landing," he was thinking of Mars.

The two major directions identified for attention in the decade immediately following Apollo 11 were: first, the further exploration of the Moon, including perhaps the establishment of a lunar base; and second, the development of a permanent manned space station supported by an Earth-to-orbit shuttle system.

Recognizing that costs are "of paramount importance," Mueller said that "unless we can substantially change our current way of doing business, we won't be given the opportunity to demonstrate the unique capabilities that space provides." This meant, among other things, minimizing the number of space vehicles in use, introducing reusable launch vehicles — the space shuttle — and developing manned spacecraft for longer duration flights.

The Space Task Group [STG] carefully examined five possible programs for NASA, of which three were consistent with the group's recommendations. One, which was not recommended, would have led to a \$10 billion funding peak for the year 1976 and a manned launch to Mars in 1981. This was considered the maximum pace at which NASA would possibly operate. The minimum pace, not favored by the group, would have suspended manned space flight altogether after Apollo and Skylab and subsequently maintained NASA

funding at a \$2 to \$3 billion a year level.

Discarding these maximum and minimum approaches to post-Apollo manned space flight, the Space Task Group focused on three options that it considered feasible.

Option I called for a mid-1980s Mars launch with an \$8 to \$10 billion peak funding by 1980; a fiscal year 1971 decision was required on the space station, the space shuttle, and the space tug, followed by a 1974 decision on the manned Mars mission.

Options II and III involved (1) the stretched accomplishment of the above missions with a 1986 Mars launch [II] or one deferred [III] to some later date; (2) the maintenance of the funding levels of the late 1960s for several years, then gradually increasing them; and (3) a fiscal year 1972 decision on the space station and space shuttle programs.

As it turned out, none of the designated manned systems recommended by the Space Task Group was approved. Moreover, of the space transportation systems identified, only the Earth-to-orbit shuttle was ultimately approved for development at a much slower pace than originally anticipated.

The reasons why the United States failed to undertake aggressive space missions based on the splendid Apollo-Saturn-Skylab foundation established in the 1960s and early 1970s are varied and complex including substantial scientific, biomedical and technical issues. But one factor was dominant: the post-Apollo climate was not propitious for another great surge into space. America's priorities were shifted elsewhere.

Frederick I. Ordway
Arlington, VA

Comparative Post-Apollo Manned Space Program Options

Milestone	Maximum Pace	Option I	Options II, III	Low Level
<i>Earth orbital elements</i>	<i>Manned space vehicle systems</i>			
Initial space station	1975	1976	1977	n.a.
50-man space base	1980	1980	1984	n.a.
100-man space base	1985	1985	1989	n.a.
<i>Lunar elements</i>				
Orbiting station	1976	1978	1981	n.a.
Surface base	1978	1980	1983	n.a.
<i>Mars</i>				
Initial expedition; Mars orbital rendezvous and landing	1981	1983	1986 (Open III)	n.a.
<i>Space transportation elements</i>	<i>Manned space transportation elements</i>			
Earth-to-orbit shuttle	1975	1976	1977	n.a.
Space tug	1976	1978	1981	n.a.
Nuclear Earth orbit-lunar orbit transfer stage	1978	1978	1981	n.a.

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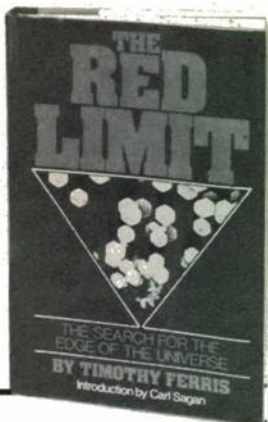
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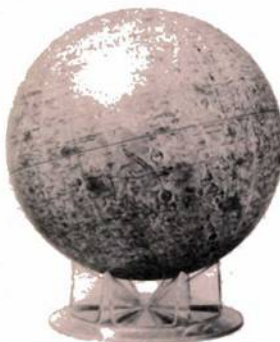
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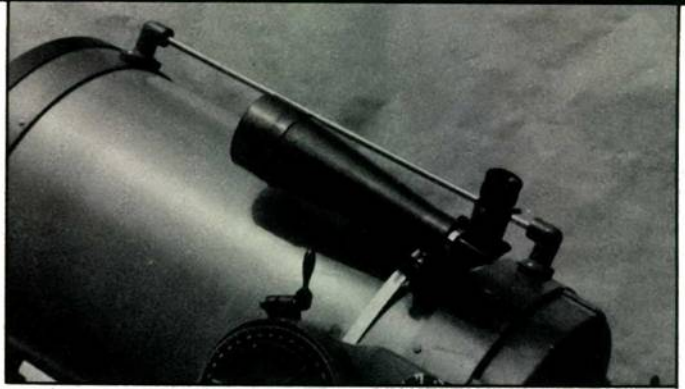
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STAR DOME

OCTOBER

by
Dewey Schwartzburg
and
James Mullaney

Last month we looked at the question of how many stars the average person could expect to see on a night of especially good seeing. We found that over the entire sky there are 22 stars of the first magnitude (i.e., stars brighter than 1.50), 69 stars of the second magnitude, 187 stars of the third magnitude, about 550 stars of the fourth, 1600 of the fifth, and 4800 of the sixth.

It's easy to see that each successive magnitude class includes just about three times as many stars as the preceding one. In other words, each step in magnitude class to fainter stars increases the number of stars in that class by a factor of almost exactly three. But we know that each successive magnitude class (see "Brightness and Magnitude," *ASTRONOMY*, July 1979) represents a change in brightness by a factor of 2.51, so we might expect that there would be about $2\frac{1}{2}$ times as many stars in, say, the third magnitude class as in the second. Why then does the number of stars in each successive class increase by a factor of *three*?

First let us suppose for the sake of simplicity that the stars are evenly distributed throughout space, and that all stars are of the same intrinsic brightness. Then the brighter stars would be those closer to us, while the dimmer ones would be more distant. To be exact, we know that stars at a certain distance from us will be four times as bright as those twice as far away, and nine times as bright as those three times as distant. This is because of the inverse square law which governs apparent luminosity.

Suppose we draw an imaginary sphere around the Earth so that all the

first magnitude stars fall within it. (Remember, according to our simplifying assumptions above, the brightest stars would be those closest to us, and any fainter ones would be more distant.) Then imagine another sphere with exactly twice the diameter of the first. By the inverse square law, this sphere would include all the stars down to one-fourth the brightness of the first magnitude stars. How many of these would there be?

Well, we know that the volume of a sphere depends on the cube of its radius (which is half the diameter). So doubling the radius of a sphere will increase its volume by a factor of 2^3 , or eight ($2 \times 2 \times 2 = 8$). Thus if there are 22 stars in the first sphere, there will be eight times as many — 176 — in the second sphere of twice the diameter of the first. But this number includes the 22 stars in the first sphere, so in fact 154 stars ($176 - 22 = 154$) will be found in the "shell" region between the surface of the first sphere and that of the second.

Another way of getting this number of 154 stars is by calculating the volume of the "shell" region. The volume of this shell will be simply the volume of the second sphere minus the volume of the first. Since the second sphere is twice the diameter of the first, if we take the volume of the first to be 1, the volume of the shell is $2^3 - 1 = 7$ — in other words, the volume of the shell is seven times that of the inner sphere, so we can expect it to contain seven times as many stars — and $7 \times 22 = 154$. Therefore there would be a total of 154 stars down to one-fourth the brightness of our first 22.

This, however, isn't very helpful in

answering our question, because in fact a single step in magnitude, as we pointed out above, represents a change in brightness by a factor of 2.51, not 4. So our second sphere would contain not just all stars of the second magnitude and brighter, but stars down to somewhere in the third magnitude class as well.

Can we calculate how many second magnitude stars there should be on this basis? We can: by the inverse square law we know that if brightness declines by a factor of four, distance increases by a factor of two — the square root of four. So if brightness declines by a factor of 2.51 (as in the case of a difference of one magnitude from, say, first to second), the distance increases by a factor equal to the square root of 2.51, which a pocket calculator quickly gives as 1.58. So if we want our "shell" region to contain all the second magnitude stars, but *only* second magnitude stars, we have to make the second sphere exactly 1.58 times larger in radius.

Now we have a sphere centered on the Earth containing all the first magnitude stars, and a second sphere of radius 1.58 times that of the first which will contain all second magnitude stars in addition to the first magnitude class. The "shell" between the two will contain all second, and *only* second, magnitude stars. In the same way we can construct a third sphere with a radius 1.58 times as large as the second, whose "shell" will contain all the third magnitude stars, and so on.

How many stars can we expect to find in each of these magnitude class shells? We saw above that the relative volume of each shell would be the cube

The brighter stars are given their proper names on the Star Dome chart. The brightest stars in each constellation are also known by their scientific names, consisting of a letter from the Greek alphabet followed by the Latin genitive of the constellation's name.



This Star Dome rendering approximates the sky as it appears at about 10:30 p.m. Local Standard Time early in the month and one hour earlier toward the end of the month. The positions of planets can be found with the help of the Planet Finder on page 32.

of its outer radius minus that of its inner radius, which we take to be 1. Then the shell will contain $1.58^3 - 1$ times as much space as that within it. $1.58^3 - 1$ equals 2.94 — or almost three. We would expect, then, that if the stars were evenly distributed throughout space and of equal intrinsic luminosity, there would be almost three times as many stars in each successive magnitude class. This is just what we find to be the case.

Of course the stars aren't evenly distributed, and aren't of equal luminosity, but there are enough of them that random variations average out over the whole. On this basis, with 22 first magnitude stars, we would expect successive classes to include 65,

190, 559, and 1644 stars. The actual figures are 69, 187, about 550, and about 1600 — in accord with our prediction. This system does break down, though, when we get to magnitudes faint enough to represent distances outside the disk of the galaxy, where there are very few stars. In fact, it was just such "star counts" down to dim magnitudes which first revealed the flattened disk shape of the galaxy to astronomers!

Close-Up

Cepheus

Ranking 27th in size among the

constellations and covering nearly 600 square degrees of the north circumpolar heavens is Cepheus. The characteristic house-shaped outline of the "starred Ethiopian monarch" is formed by the stars Alpha, Beta, Zeta and Iota at the four corners and by Gamma at the top of the "roof." Although relatively faint, this figure is readily traced out on a dark night.

Many observers have remarked that Cepheus appears much more barren to the unaided eye than with the telescope. Indeed, while nearly all of this month's selected objects can be spotted without optical aid, their hidden beauty becomes apparent only in a small glass. With each increase in aperture, the wonders multiply in



overwhelming profusion.

Cepheus is rich in double and multiple stars for the small telescope. Burnham's *Celestial Handbook* listing well over a hundred such objects here. Many of these have easy separations and striking color or magnitude contrasts to delight the celestial sight-seer night after night. And a dense section of the autumn Milky Way passes through part of the constellation, offering, as Webb remarked, "splendid sweeps and curious groups between Alpha and the Galaxy."

Delta (δ) Cephei

The primary stellar attraction of Cepheus is the stunning and dynamic variable-double sun Delta (δ) Cephei. As most star maps or atlases show, the southeastern corner of Cepheus'

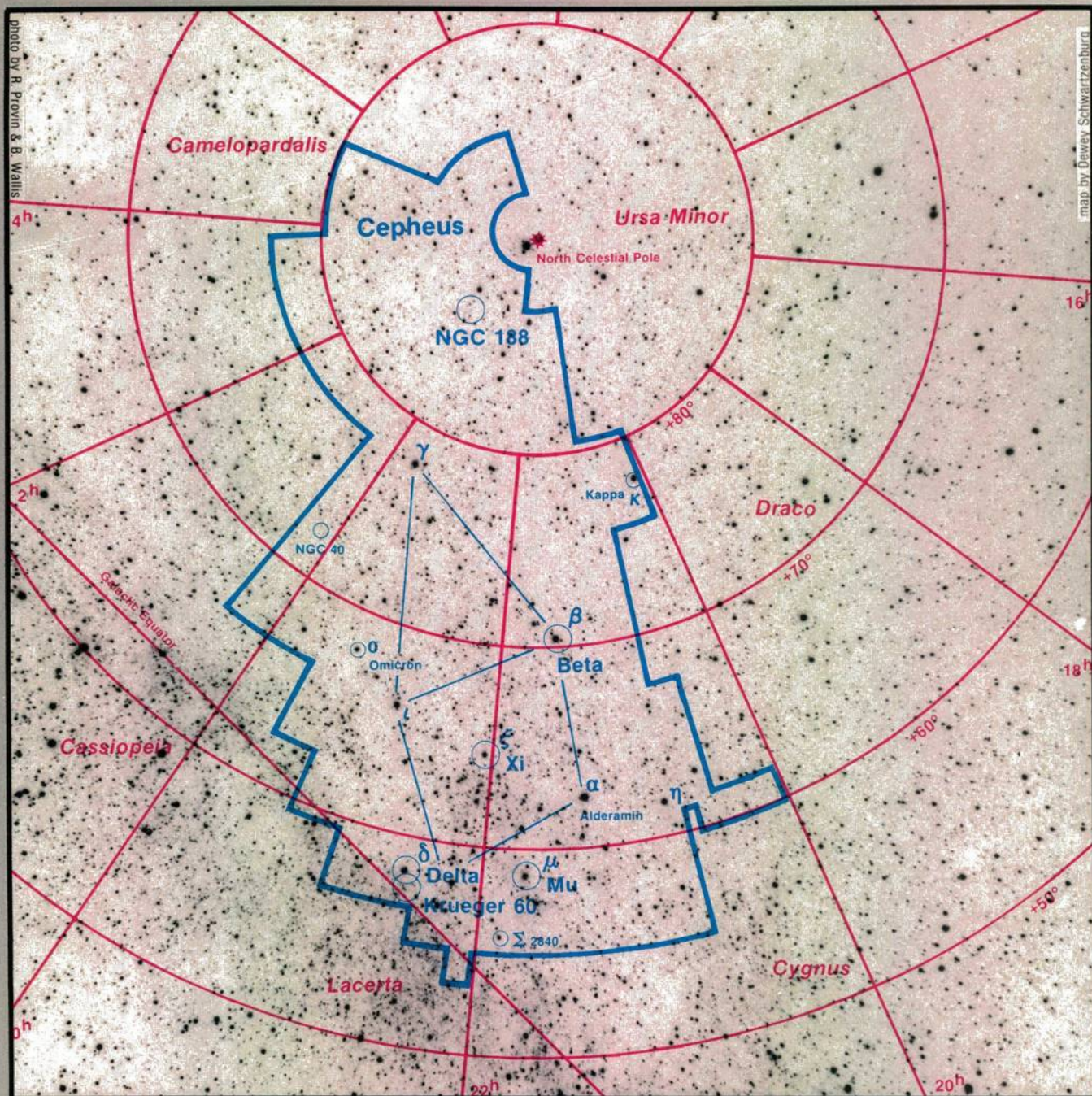
heavenly house is actually occupied by three objects rather than one — the stars Zeta (ζ), Epsilon (ϵ) and our target itself.

Delta is the prototype of the famed Cepheid variables which have played a vital role in establishing the distance scale of the universe. Found in many remote clusters and galaxies, these "standard candles" serve as reliable distance indicators due to a distinct relationship between their periods of varying brightness and intrinsic (or real) luminosities. At its distance of some 1300 light-years, Delta is the closest and brightest representative of its exalted class.

The variability of Delta Cephei was discovered by John Goodricke (of Algol fame) in 1784. This restless giant

pulsates from 3.6 to 4.3 magnitude in a period of 5.37 days, during which time its spectral type also changes — from F5 to G3. Neighboring Zeta and Epsilon make good comparison stars by which to follow its variation in brightness, their visual magnitudes being 3.4 and 4.2, respectively.

Aside from being an important variable, Delta is also a beautiful double star for small telescopes. The yellow primary has a 6.3 magnitude blue (spectral class B7) companion 41 seconds of arc distant in position angle 192° (or nearly north-south on the sky). This duo is quite striking even in a 2-inch refractor at 30 power — indeed, much more magnification seems to spoil the contrast effect by separating the components unduly.



Webb described Delta as an "especially fine pair, somewhat like Beta Cygni (Albireo)," and Smyth noted the tints as deep yellow and cerulean blue. While nearly all observers agree in calling the companion blue, some find the primary pale orange in cast. Muir den saw "fine contrast" here and Olcott considered this object a "beautiful... field-glass double." It appears on most lists including Flammarion's lineup of the 25 best pairs and Pickering's roster of the sky's 60 finest objects. Placing it under his "colored double stars" category, the latter observer remarked that "wide doubles that are variable are unusual."

Over the years, various values for the brightness of Delta's companion

have been assigned, ranging from 5.0 to 7.5. Have these been affected by the variation of the primary itself? Another question concerns Barns' description of this pair: using his 10-inch reflector in the clear skies of California, he noted "two lambent clusters in field." Can you see these apparent concentrations in the Milky Way background with your telescope on a dark night?

Krueger 60

Just 15 minutes of arc west and about 45 minutes south of Delta lies what Barns called "a faint but remarkable double" star. This is the amazing red dwarf binary/flare star system known as Krueger 60, one of our nearest stellar neighbors at just under 13 light-years away (only a

hundredth the distance of Delta). Although located within the same low power eyepiece field as our last object, at least a 4-inch telescope will be required to identify it with certainty.

Six-inch and larger apertures at medium to high magnifications will show an apparent triple star in its place. Krueger 60 itself is a very close pair of 10th and 11th magnitude stars currently 2.4 seconds apart near position angle 60°. Both are M-type red dwarfs and can be distinguished from surrounding field stars by their distinct ruddy hue, even if not seen as resolved or elongated in your scope. A 10th magnitude field star lies about 60 seconds from the close pair — its separation has nearly doubled over the past century due to the rapid proper

motion of Krueger 60 itself.

It's of interest to note that it was the wide pair of stars that Krueger himself discovered, the close one being found later by the great double star observer S. W. Burnham. This duo forms a fast-moving binary system having a period of just 44½ years. In addition, the fainter component is a flare star: also known as DO Cephei, it is subject to striking and unpredictable outbursts in brightness over a period of a few minutes! As Robert Burnham, Jr. (no relation to the above Burnham) points out, "the frequency of flares is not well known, but it appears that a number of hours of spot-checking are required before one is accidentally caught."

R. Burnham goes on to state that "though not a brilliant object, Krueger 60 is of great interest to any serious observer. A good 6-inch telescope used with fairly high power will usually resolve the pair, and changes in position angle, due to the binary motion, can be detected in an interval of only a few years. The chance of detecting a flare adds to the interest in observing this unusual system." Few of the classic observers had anything to say about this object, but Webb did note it as "a most interesting object; the north star of a triangle, the others 8.5 magnitude."

Here in the same eyepiece field are two dramatically different variable-double star systems — the one easy for the novice using the smallest glass, the other challenging the skills of the well-equipped seasoned observer.

Beta (β) Cephei

Our next offering ranks as perhaps the second finest of this region's host of double stars after Delta itself. This is Beta (β) Cephei, an unequal pair whose charm lies in its magnitude rather than color contrast. Look for it at the

northwest corner of Cepheus' house (on the same side as Alpha [α]).

Beta consists of 3rd and 8th magnitude suns 14 seconds apart in position angle 250°. Their spectral types are B2 and A3, respectively, and both stars appear blue-white to most observers. A 3 or 4-inch scope at 45 to 60 power shows the little star tucked neatly beside its hundred-times brighter primary. Larger instruments seem to enhance this magnitude contrast, and with 8 to 12-inch apertures this pair is one of the finest doubles of its kind in the sky.

Brown called Beta a "nice object for a 3-inch refractor." Smyth gave its tints as white and blue at one time, and later as yellowish and flushed blue. Webb saw the components as white and blue, Franks as greenish-white and purple, and Dembowsky as yellow and violet. Still other observers like Muir, and Bernhard, Bennett and Rice gave the colors as greenish-white and blue. How do you find them in your scope?

There has been little change in the position angle and separation of Beta's components since they were first measured a century ago, but no doubt they form a binary system of very long period. The primary star was once thought to be a very rapid spectroscopic binary itself, one with a period of revolution of just 4½ hours. However, later work showed it to be a variable of the Beta (β) Canis Majoris type instead. Likewise, early distance determinations placed this pair some 500 light-years distant, but modern values are nearly twice as great.

Xi (ξ) Cephei

Shining right in the middle of Cepheus' house — like a light in a window — is yet another fine double star for small telescopes. This is Xi (ξ) Cephei, a 4.6 and 6.5 magnitude combo

separated by only 8 seconds near position angle 250°. Lying some 80 light-years from us, these A3 and F7 suns present a delicate color contrast that observers seem to have trouble in pinning down.

Among the various hues assigned to Xi's components over the years are yellow and blue, and white and tawny or ruddy (Webb), flushed blue and pale lilac (Smyth), pale yellow and blue (Struve), and both bluish (Olcott and Brown). Still other impressions are white and violet, and pale green and purple. A 4 or 6-inch reflector, equipped with well-corrected modern eyepieces, will show the primary as yellow-white and the companion as blue or perhaps lilac to most eyes. Medium powers are best for separating this rather tight pair and larger apertures enhance the tints in this case.

Burnham calls this slow-moving binary system "a fine double star, usually considered the most attractive in the constellation, with the possible exception of Delta itself." Based on your own observations, in what order would you rank Delta, Beta and Xi Cephei in terms of overall visual attractiveness and appeal?

Omicron (ο) Cephei

Three degrees northeast of the star Iota (ι) resides another colorful celestial duo, this one Omicron (ο) Cephei. Since sky directions can be confusing near the pole, a line drawn from Xi through Iota can also be used to find its position. Here we find a close blend of 5th and 8th magnitude stars just 3 seconds apart in position angle 215°. Another slow moving binary system, this pair lies nearly 800 light-years from us.

Norton considered Omicron a "test for a 2-inch telescope," but at least twice that aperture will be needed for a good view and even larger ones to fully appreciate the colors here. The K0 primary and F6 secondary result in a pleasing contrast of hues. Colas included this object in his list of the finest colored pairs, giving the tints as gold-yellow and azure. Smyth found then very yellow, very blue, and again, orange-yellow and deep blue in his 6-inch refractor. Muir, and Webb yellow and greenish, and Webb yellow and yellowish-green, adding the comment "not remarkable as a contrast." Do you agree with the poor assessment made over a century ago by this great visual observer?

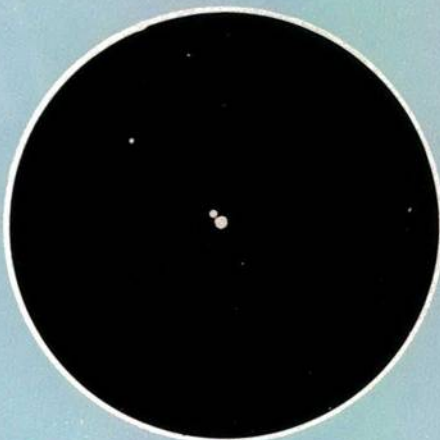
Barns brought out an interesting point in his account of Omicron: "Their primrose and lilac tints seem to appear stronger with relatively poor seeing, or through a faint aurora, as is the case with circumpolar stars in particular. The sharpest skies are not always the

Selected Objects — Cepheus

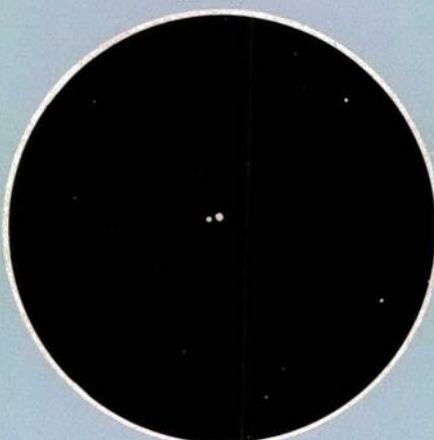
Object	Type	Mag.	Size/Sep. Per.	R.A. (1950)	Dec.
NGC-40	■	10.2	60"x38"	00 ^h 10 ^m	+72°15'
*NGC-188	○	9.3	15'	00 ^h 39 ^m	+85°03'
Kappa (κ)	★²	4.4,8.2	7"	20 ^h 11 ^m	+77°34'
*Beta (β)	★²	3.3,8.0	14"	21 ^h 28 ^m	+70°20'
*Mu (μ)	♠★	3.7-5.0	--	21 ^h 42 ^m	+58°33'
Σ 2840	★²	5.5,7.3	18"	21 ^h 50 ^m	+55°34'
*Xi (ξ)	★²	4.6,6.5	8"	22 ^h 02 ^m	+64°23'
*Krueger 60	★³	10,11,10	2",60"	22 ^h 26 ^m	+57°27'
*Delta (δ)	♠★,★²	3.6-4.3,6.3	41"/5.4 ^d	22 ^h 27 ^m	+58°10'
*Omicron (ο)	★²	5.5,8.0	3"	23 ^h 17 ^m	+67°50'

*Detailed in Close-Up

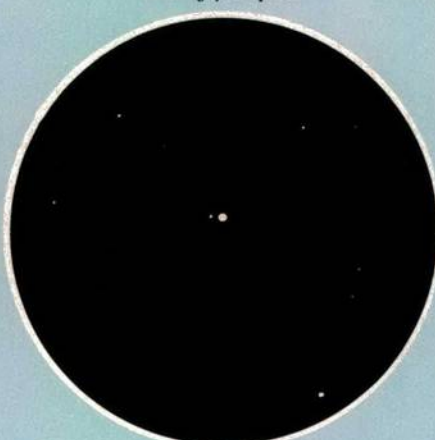
- ★ Star
- ♠★ Regular Variable
- Open Cluster
- §0 Elliptical Galaxy
- ★¹ Bright Star
- ♠★ Irregular Variable
- Globular Cluster
- §5 Spiral Galaxy
- ★² Double Star
- ♠★ Eclipsing Variable
- Planetary Nebula
- §7 Barred Spiral Galaxy
- ★³ Triple Star
- Bright Diffuse Nebula
- §# Peculiar/Irregular Galaxy

Theta (θ) Cephei

145x N 6 inch reflector

Xi (ξ) Cephei

60x N 6 inch reflector

Beta (β) Cephei

60x N 6 inch reflector

best for comparative observation." Color studies on unsteady nights give much the same effect as a slight defocusing of the image — both spread the light over a greater area of the retina, making the perception of delicate hues more definite. Why not verify Barns' remarks from your own observations over a series of nights — especially now with solar activity rapidly on the rise and aurorae becoming more frequent again.

Mu (μ) Cephei

For a change of (celestial) fare, our next object is a single but highly-tinted variable sun that's sure to bring exclamations of delight at the eyepiece. This is Mu (μ) Cephei, renowned as Sir William Herschel's Garnet Star. You'll find it forming a squat triangle with Alpha and Zeta at the base of the house. It stands out nicely against the Milky Way background when near maximum light, and its remarkable color stands out even in binoculars and finder scopes.

Mu Cephei is an irregular variable star whose light slowly waxes and wanes between magnitudes 3.7 and 5.0 over a rough period of 5 or 6 years. A supergiant sun of spectral class M2, it lies nearly a thousand light-years away. A special feature of great interest in its spectrum is the presence of water vapor (actual steam!) in its relatively cool outer atmosphere.

Herschel stated that Mu "is a very fine deep garnet colour." As Webb pointed out, this becomes especially obvious when its warm light is compared to that of a white star like Alpha Cephei (spectral type A7). He also noted that it looked "deep orange, not crimson" in his 5.5-inch refractor.

Mu's visual color seems to depend on the size and type of telescope used to view it, and also is suspected of actually varying with time. It typically appears vivid red in binoculars and finders, ruddy orange in a 3-inch

refractor, rich orange in an 8-inch reflector and yellow in a 13-inch refractor. Increased light grasp appears to diminish the depth of tone with this object.

Barns described Mu as "curious" and Muirden as "shining like a drop of blood." Burnham calls it "perhaps the reddest star visible to the naked eye in the northern half of the sky," and points out that "according to some observers, the star varies in color as well as light. It usually appears a deep orange-red but on occasion seems to take on a peculiar purple tint." Can you confirm this remarkable possibility from carefully made color estimates with your telescope?

Viewed through the porthole of a telescope's wide-field eyepiece on a dark transparent night, Mu Cephei shines like some colossal interstellar traffic beacon amid the host of suns circling the distant hub of our vast star city — the Milky Way Galaxy.

NGC-188

Our final selection from the wonders of the Cepheus region is an unusual and astrophysically important open star cluster. This is NGC-188, thought to be the oldest member of its class in our part of the galaxy — 12 to 14 billion years old! It lies in an obscure region about 4° from Polaris in the direction of Gamma (γ) Cephei. To find it, sweep with a low power eyepiece on a 6-inch or larger scope near the naked-eye star 2 Ursae Minoris, preferably on a dark (moonless) transparent night.

Overlooked by William Herschel, this ancient cluster was found by his son John. The *NGC* (based heavily on the work of the Herschels) describes it as a "cluster, very large, round, 150 to 200 stars of the 10th to 18th magnitude." These glow with the combined light of a 9th magnitude star and occupy an area 15 minutes across. Classified as very loose and irregular, about 70 stars can be glimpsed in medium-sized amateur instruments

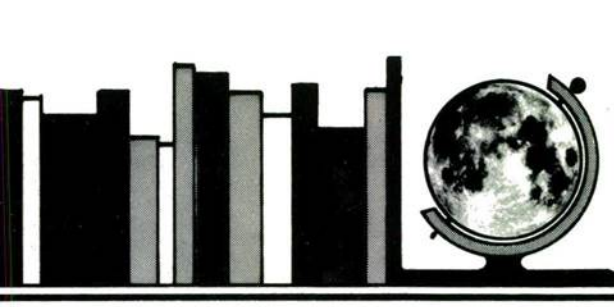
Delta (δ) Cephei

45x N 6 inch reflector

using magnifications between 50 and 100 diameters on a good night.

Giving the distance to this clan as slightly over 5,000 light-years, Burnham describes it in part as follows: "The cluster can be detected with a 6-inch or 8-inch telescope using low power, and appears as a large but dimly luminous spot with only a few of the brighter members showing individually." Little else is to be found in the observational literature concerning its visual appearance — a lack some well-equipped observer might like to fill.

To catch a glimpse of NGC-188 — however muted its appearance by time and distance — is a thrilling experience when we realize that we are viewing the light of suns nearly as old as the universe itself. Here is a swarm of stars whose thermonuclear fires burned brightly long before our own sun came on the cosmic scene — that were present to witness the birth of the Earth itself! Well has von Humboldt observed that "The stars bind together all men and all periods of the world's history. As they have seen all from the beginning of time, so shall they see all that will come hereafter."



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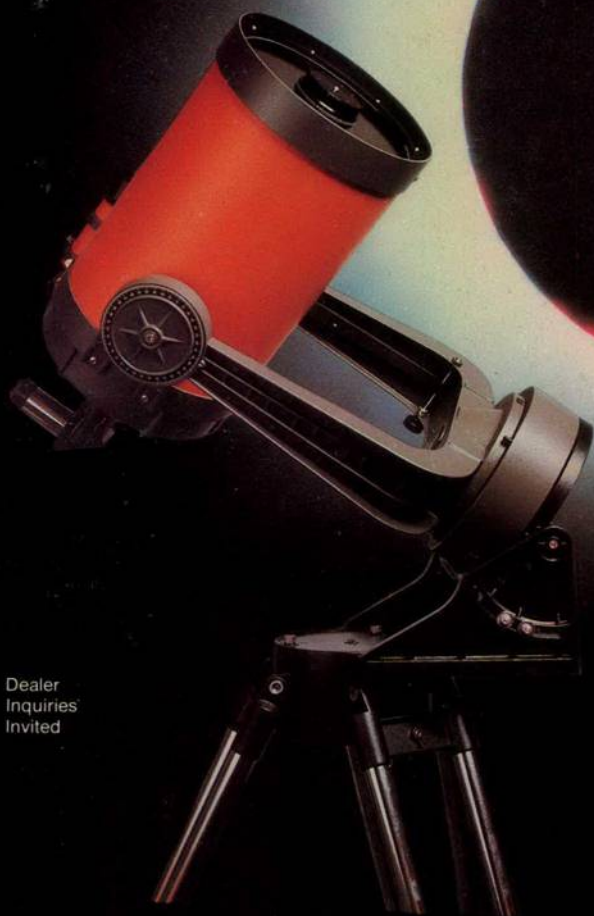
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